Department of Indian Affairs and Northern Development

Northwest Territories Water Resource Study

March 1982

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Dear Mr. Waroway:

Northwest Territories
Water Resource Study

We are pleased to submit our report on the water resources of the Northwest Territories. This report updates the water resources study completed by Acres Consulting Services Limited in 1976. In carrying out this assignment we have endeavored to make full use of the limited data base available and to present the results in a suitably practical form for use by individuals who do not have an extensive background in hydrology.

The intent of the study is to provide regional hydrologic information for the Northwest Territories and Arctic Islands. The results are satisfactory for preliminary project planning, however, the relationships should not be used for detailed planning or engineering. For these later purposes, site-specific hydrologic studies should be performed.

The data base for this study is significantly improved over that available for the previous 1976 study and estimates of hydrologic characteristics in ungauged catchments can now be made with increased confidence. However, data from new sites that is currently available only for recent years will, after an additional collection period, provide a much firmer base for re-evaluation of the hydrologic relationships. We therefore recommend that this study be updated in 5 years using the more comprehensive data.

We wish to thank you for your help during the study and trust this report meets your present needs.

Yours very truly

I. K. Hill
Project Manager

IKH:rs

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1 - SUMMARY

1 - SUMMARY

This project updates the Northwest Territories Water Resource Study completed by Acres Consulting Services Limited, in 1976.

1.1 - Objectives

The objectives of this study of the water resources of the Northwest Territories are

- compilation and analysis of existing data. Included in this work package is a search of all pertinent data banks to identify research conducted in Arctic regions since the last Northwest Territories Water Resource Study in 1976.

- derivation of methods for extending hydrologic data on measured watersheds in order to estimate key features of the hydrologic cycle in other areas. Specific features of interest are the quantity of annual runoff and its variability, the statistics of low streamflows, and flood peaks.

- documentation of the hydrologic regime of rivers which flow north across the Sixtieth Parallel into the Northwest Territories

- documentation of the basic hydrologic characteristics of the Mackenzie River main stem at one station

- identification of data deficiencies revealed by the study, with a view to relating new data needs to ongoing hydrometeorological network expansion.

1.2 - Overall Approach

A literature search for new methods of regional hydrologic analysis and for new studies on specific northern basins showed that little new research has been done in this field in the past 5 years. This study has, therefore, been conducted very much as an update of the previous work in 1976. The study makes maximum use of existing data on climate, streamflows, terrain, geology and vegetation in order to derive regional hydrologic characteristics. Preference is given to uncomplicated methods of analysis appropriate to the data base.

1.3 - Results

Results of the study show the following.

- A literature review into climatologic and hydrologic research in northern regions has shown little new information of value to this study. One exception is a detailed report on the climatology of the Arctic Islands by J. B. Maxwell (Reference 3). This report is quite comprehensive and its major findings have been included in our analysis.

- A map of mainland mean annual runoff for the period 1962 to 1980 has been prepared. This map shows mean annual runoff varying from 100 mm in the central Northwest Territories to 500 mm in the Cordilleran mountains. In the Arctic Islands, the annual runoff is best estimated from precipitation maps since losses are low and runoff data is sparse. Annual precipitation maps have been prepared for both the mainland and the Arctic Islands for base periods of 1941 to 1980 and 1962 to 1980.

- Annual 30-day low flows vary from zero in some small basins to as much as 70 percent of mean annual flow in larger basins with large amounts of lake storage. Regional analysis showed that the 30-day low flows were related to mean annual discharge, proportion of lake area and mean daily February temperature in the Canadian Shield and only to mean annual discharge in the Cordillera and Interior Plains.

- Regression equations have been developed to produce an estimate of annual low flows at ungauged catchments on the mainland. Although the additional data available since 1976 have not improved the estimated low flows, the confidence which can be placed in the estimate has improved.

- Regional flood frequency analysis has shown that the Index Flood Method produces the best estimates of floods on ungauged catchments, as was the case in 1976. New regional flood frequency curves have been developed for each physiographic region using all data now available.

- At the Sixtieth Parallel, there is a net flow of water into the Northwest Territories from the provinces and from the Yukon. Most of this water, about 180 billion m^3/yr, is conveyed by three major rivers--the Liard, Hay and Slave. The flow out of the Territories is confined to minor systems, principally along the Manitoba border.

The generality of results is limited because of the vast area included in each region, however, the data base is now much broader than it was in 1976.

1.4 - Data Deficiencies

In the period 1976 to 1980, 52 new stream gauging stations have been installed in the Northwest Territories. The distribution is as follows.

Cordillera - 5
Interior Plains - 17
Canadian Shield - 25
Arctic Islands - 5

Gauges which had a short period of record in 1976 now have sufficient data to permit analysis. As a result, the streamflow data base in the Northwest Territories has substantially improved to the point where many of the data gaps present in 1976 have been plugged. In total, 23 additional gauges have sufficient data for analysis in this study, thus bringing the current total to 51 gauges from the previous 28.

There remains a scarcity of streamflow data from rivers flowing north to the Arctic Ocean and east to the Hudson Bay, however, gauges that are now in operation with a few years of data will be much more useful in a future update of this work. Installation of additional gauges in this area is not considered a high priority.

Areas where additional stream gauges would assist in defining regional runoff and flood characteristics have been identified and are discussed in Section 8.

Streamflow data for the Arctic Islands remain sparse, however, with the additional gauges installed over the past 5 years, a more in-depth regional analysis will be possible at the time of the next study update. It will be necessary to ensure continuous recordings at those gauges which have been installed.

1.5 - Further Studies

Studies which would improve the knowledge of the water resources of the Northwest Territories were identified in the 1976 study. Little has been done in the way of research in these areas since that time and the recommendations stated in the previous report still stand.

In particular, these are

- research studies into elements of the hydrologic cycle at high latitudes. (Some work has been carried out in this area by Woo--see the bibliography.)

- studies of the influence of vegetation types on the hydrologic cycle

- groundwater studies, particularly to the nonpermafrost forested areas of the Northwest Territories

- studies of analytical techniques for the prediction of flood characteristics on ungauged watersheds. (Some research was carried out in this area by Jolly, Pitcher, Solomon and Waroway--see the bibliography.)

- physiographic data compilation from large-scale maps for existing drainage basins.

A large number of stream gauging stations installed in the past 5 years have an insufficient data base to be included in the analysis of this study. A further update of this study is therefore recommended 5 years from now at a time when these new stations have a long enough record for analysis. This further update with a longer data period could also allow for regional analysis of skewness. The data base used in this study has been stored on computer tape in a convenient form to facilitate a study update.

1.6 - Application of Results

The hydrologic relationships developed in this report are intended to provide information suitable for preliminary planning, or for establishing the approximate magnitude of the hydrologic characteristics of a stream or river. Accordingly, the relationships should not be used for detailed project planning or engineering. For these latter purposes, site-specific hydrologic studies should be performed.

2 - INTRODUCTION

This report covers the water resource inventory, management alternatives and potential uses of the water in various northern regions. The study covers the entire Northwest Territories, with greater emphasis on the mainland. Special emphasis was placed on documenting the hydrologic regime of significant rivers at the Sixtieth Parallel and on the Mackenzie River main stem. The detailed objectives of the study are to

- analyze and summarize available data relevant to qualitative and quantitative illustration of the hydrologic cycle in various basins and regions

- derive standard hydrologic parameters to characterize all basins with hydrometric data available

- develop a method for estimating the probability of occurrence of floods from rainfall and snowmelt through analyzing physiographic and climatological data. Draw maps showing isolines of the parameters to be used in these estimates.

- recommend prodedures for the practical application of the theoretical methods used to estimate hydrologic characteristics for basins with no hydrometric data available. Illustrate by examples and discuss limitations, precision and anomalies.

- comment on the existing tentative program for hydrometric network expansion in the Northwest Territories and recommend immediate and short-term changes in hydrometric and climatologic data collection

3 - HYDROLOGY OF THE NORTHWEST TERRITORIES

The hydrology of the Northwest Territories is controlled partly by climate and partly by physiographic features. This section, therefore, contains a description of the climate and hydrology of the four physiographic regions into which the Northwest Territories can be subdivided for study purposes--the Cordillera, Interior Plains, Canadian Shield and Arctic Islands.

A literature search for recent documents relating to the hydrology and climate of the Northwest Territories was performed and is summarized in this section. The remainder of this section is basically a summarized version of the 1976 report (Reference 1).

3.1 - Literature Review

An extensive review of recent publications (since 1975) concerning the hydrology and climate of the Northwest Territories was undertaken. In total, 11 computer abstraction systems were searched for relevant documents. These searches were done both by topic and keyword and by geographical location. The relevant papers that were found are listed in the bibliography along with previous documents which were found to be useful. These papers are discussed below under the separate categories of climatology and hydrology.

3.1.1 - Climatology

The climate of the Arctic Islands was comprehensively assessed by J. B. Maxwell in 1980. Five climatic

regions were identifed, subdivided and delineated by an analysis of major climate controls. Short discussions of the climatic characteristics of each subregion are given, and tables outlining values of selected climatic elements are presented. This document provides a comprehensive overview of the climatic characteristics of the Canadian high Arctic.

A publication by R. J. Fletcher and G. S. Young, Climate of Arctic Canada in Maps, provided some supplementary information about the climate of the Northwest Territories, but the maps were not found to be particularly relevant to the current study.

3.1.2 - Hydrology

Many small hydrologic studies, particularly for the Arctic Islands, are documented. A number of these studies are by M. K. Woo. His work relates primarily to very small high Arctic basins. Similar basin studies are documented separately by Ambler, Anderson, Ryden and Vincent (see the bibliography). Most of these studies apply strictly to the high Arctic and are not particularly significant to the current study which concentrates on the hydrology of the mainland.

A study by Jolly, Pitcher, Solomon and Waroway looked at an alternative analytical technique for regional hydrology. An attempt was made to relate flood magnitudes to channel width measurements by various techniques. The results of the analysis show that a relationship does exist, but the results are not an improvement over those found by more conventional regional analyses as presented in this report.

3.2 - Climate

The Atmospheric Environment Service (AES) of the Department of the Environment obtains and publishes data from the meteorological stations in the Northwest Territories. These stations are operated by private and public agencies, including AES and the Ministry of Transport.

A good discussion of the large-scale meteorological forces which drive the weather systems in the Arctic is presented in Reference 2. A recent Environment Canada publication (Reference 3), by J. B. Maxwell, gives a detailed analysis of the climate of the Arctic Islands. A brief description of the meteorological factors which directly affect runoff is presented below.

The Arctic has been described as a "polar desert". Plates 1 and 2 are mean annual isohyetal maps for the period 1941 to 1980 which show that the mean annual precipitation is low--ranging from less than 100 mm to about 350 mm over most of the Territories, with only the Mackenzie Mountains receiving more. The Arctic is characterized by stable air and thus receives very little convective precipitation (e.g., thunderstorms). Precipitation is mainly frontal in nature, generated at the leading edge of low-pressure areas.

There are a number of factors which modify precipitation locally. In coastal regions, precipitation, in general, and snow flurries, in particular, are increased in months when open water exists. Cold, dry air moving over open water warms and becomes saturated with water vapor. When the warmed air mass encounters cold land, condensation and subsequent precipitation result. Major mountain ranges in the Cordillera and along the eastern coasts of Baffin and

Ellesmere islands affect the climate by altering the movement of air masses and, in particular, the precipitation patterns, through orographic lifting.

A significant characteristic of the hydrologic cycle in the Arctic is the rapidity of snowmelt. As summer approaches the amount of incoming solar radiation increases quickly as the days lengthen. The spring melt spans a short period (about 1 week) primarily because the daily temperature rise is steady with only minor diurnal fluctuations. A short melt period affects runoff in two major ways.

- There are few water losses, particularly in basins with little surface storage.

- There is a high runoff intensity leading to short runoff time and high peak flows.

Evaporation in the Arctic occurs mainly during the 4-month period from June to September when temperatures and solar radiation are higher than in winter. Transpiration is low in the region north of the tree line due to sparse vegetation. South of the tree line transpiration and evaporation increase significantly to a point where they can exceed 50 percent of total precipitation.

3.3 - Regional Hydrology

3.3.1 - Data Base

Streamflow data from a number of gauge locations in the Territories are collected and published by the Water Survey of Canada, a division of the federal Department

of the Environment. Plates 7 and 8 show gauge locations on the mainland and Arctic Islands respectively. Plate 9 summarizes the periods of record for the gauges shown.

Precipitation data are available from the AES of Environment Canada. Plates 1 to 4 show the locations of precipitation stations used in this study, and Table A-3 in the appendix summarizes the data.

Physiographic data were extracted from 1:500 000-scale National Topographic System maps published by the Surveys and Mapping Branch of the Department of Energy, Mines and Resources. Maps to a scale of 1:250 000 are available for the entire Northwest Territories and to a scale of 1:50 000 for some areas. These maps may be used for hydrologic studies done at a more detailed level.

3.3.2 - Delineation of Hydrologic Regions

The study area is much too large and diverse to be treated as a single hydrologic region. In the 1976 study (Reference 1), physiographic and climatic differences led to the division of the Territories into four regions. The current data base does not justify further subdivision and consequently the same regions were adopted in this study.

In the mainland Northwest Territories, there are three major physiographic regions--the Cordillera, Interior Plains and Canadian Shield. The various physiographic areas of the Arctic Islands were treated as a single

region for analyses since there are insufficient hydrologic data for regional hydrologic analysis. The extent of each region is shown on Plates 10 and 11.

3.3.3 - The Cordilleran Region

The Cordilleran Region (see Plate 10) is defined as the area of the Northwest Territories west of the Mackenzie River plus the Franklin Mountains on the east side of the river.

The hydrologic regime of the drainage basins in the Cordilleran Region is strongly influenced by the continental climate, and characteristically steep topography with little surface storage. The mean annual runoff (see Plate 12) can vary from 200 to 600 mm, depending on local variations in precipitation, snow accumulation and vegetation.

A major portion of the water losses evident from comparing precipitation and runoff (see Plates 3 and 12) occurs as transpiration from the vegetation cover at lower elevations and south of the tree line.

By November of each year, streamflow has dropped close to its base flow level, a level which persists into the following May. The mean annual low flow is generally 10 percent of the mean annual flow in a basin. A more detailed analysis of this relationship is given in Section 5.

Steep slopes and a lack of surface and groundwater storage cause rivers to peak quickly with the occurrence of spring snowmelt. Typically, the peak

discharge of 5 to 10 times the mean annual flow occurs in June. Close to 80 percent of the total yearly runoff occurs in the 4-month period from May to August. In large basins (greater than 2,600 km^2), the peak annual flood occurs as a result of snowmelt. As the basin size decreases, it becomes more likely that rainstorms in June, July or August cause some floods greater than snowmelt floods.

3.3.4 - The Interior Plains Region

The Interior Plains Region (see Plate 10) extends essentially from the Mackenzie River in the west to a line running through Great Bear Lake, along the Camsell River, through Great Slave Lake and along the Slave River.

The following physiographic features of the region influence the hydrology.

- Relatively Flat Topography - This results in longer runoff times and therefore attenuation of flood peak discharges. Despite the topography, lake storage is small compared to the Shield basins. On-channel surface storage, made up of on-channel lakes and wide floodplains, appears to have a significant effect in altering the flood regime of the rivers. These characteristics can be expressed by the slope of the river.

- Forest Cover - Most of the region (except north of Great Bear Lake) is treed with tamarack and spruce which act to increase evapotranspiration, extend the spring thaw through solar protection to the snowpack, and decrease the runoff rate by foliage and ground litter interception.

- Discontinuous Permafrost - The majority of the region falls within an area underlain by discontinuous permafrost. Permafrost affects the hydrologic cycle by decreasing the available groundwater storage, thereby increasing the proportion of surface runoff and decreasing the basin response time.

- Surficial and Bedrock Geology - The soils of this region are dominantly poorly drained organics underlain by unconsolidated glacial material with few bedrock outcrops. These types of soils are likely to have significant groundwater flows.

The hydrologic regime, in terms of both flood and low-flow response, is dependent on the factors discussed previously, particularly the flat topography and lack of surface storage.

Basins with a small amount of storage exhibit marked "peakiness", that is, a high but unsustained flow. The low flows are not naturally regulated and the annual low flows drop to a very small fraction of the mean annual flow--frequently zero in some basins.

3.3.5 - The Canadian Shield Region

The Canadian Shield Region in the mainland Northwest Territories extends from the Interior Plains in the west to Hudson Bay in the east (see Plate 10).

The following physiographic features have a marked effect on the hydrology of the region.

- Flat Topograhy - The combination of flat topography and previous glacial activity has left the Canadian

Shield with a very large proportion of lake area. Shallow stream slopes, in conjunction with large lake area, increase basin response time, thus moderating runoff patterns.

- Forest Cover - The effect of forest cover on mean annual runoff is well demonstrated. In moving south from the northern coastline, runoff increases. Toward the tree line runoff starts to decrease (despite increasing precipitation) in response to increased losses.

- Permafrost - A large part of the region lies within the zone of continuous permafrost, and the balance in a zone of discontinuous permafrost (see Plate 10). This increases available groundwater storage, decreases infiltration, and thus increases surface runoff relative to precipitation.

- Surficial and Bedrock Geology - The entire Shield Region shows the effects of recent glaciation. The western section has large Precambrian bedrock exposures and consequently little groundwater storage. Moving east, the terrain consists of glacial debris with some areas of exposed bedrock. However, the existence of permafrost prevents an increase in groundwater storage. Throughout the region, glaciation has left a multitude of surface depressions filled with water, many with indefinite outlets. Lake area can comprise over 30 percent of a drainage basin.

The hydrologic regime in the Canadian Shield is dominated by the effects of large amounts of lake storage. In large basins (greater than 40 000 km^2), the

snowmelt flood is the largest of the year. In medium to small basins, the peak daily flow can result from summer rain occurring on a basin which is saturated by snowmelt. In both large and small basins, the effects of storage generally reduce the ratio of mean annual flood peaks to mean annual flow. In most cases, natural regulation through surface storage is sufficient to maintain winter low flows at reasonably high levels.

3.3.6 - The Arctic Islands

The network of currently operational stream gauges is very sparse, and the records are limited in value due to their often intermittent nature. Limitations imposed by this sparse data base restrict the information that can be obtained from it to a general description of the hydrologic cycle.

The streamflow data base (see Plate 9) indicates that the data which have been collected to date are of limited value, since complete records for a water year are often not available. The streamflow gauging network (see Plate 8) is sparse and the stations represent only coastal (i.e., easily accessible) locations.

The physiographic characteristics of principal hydrologic significance are the low to moderate relief (with the exception of the glacier-fed streams on the eastern islands), the general absence of lake storage, and the presence of continuous permafrost close to the ground surface. These factors, combined with the long intense winter and short summer, produce a hydrologic regime characterized by rapid response to snowmelt and rainfall events, and a reduction to zero flow soon after the onset of winter.

Total runoff appears to be nearly equal to measured annual precipitation at nearby meteorological stations. In some cases, measured runoff exceeds precipitation, an anomaly which is probably caused by one or more of the following

- underestimation of total station precipitation combined with very low losses

- failure of precipitation station to represent the catchment precipitation adequately

- redistribution of snow by wind.

While it is logical that losses can be expected to be very low in this area, it is probable that the most significant factor is the underestimation of precipitation as a result of complications brought about by blowing snow. Reference 3 by J. B. Maxwell presents an Arctic Island mean annual isohyetal map which includes a 50 percent increase in precipitation to account for these possible errors. Plates 1 to 4 in this report are based solely on the recorded precipitation with no such adjustment.

Without any recorded exceptions, flow in Arctic Island streams stops in the winter, and begins again when snowmelt commences in the spring.

The annual flood peak usually follows the first snowmelt or "rain-on-snow" event. The first peak is often the most spectacular and sometimes the most damaging, since it is often accompanied by ice and other debris which may produce higher flood stages than a subsequent peak which may be higher in flow magnitude. After snowmelt is complete, flows generally recede rapidly and are intermittently increased by summer rainstorms.

4 - ANNUAL RUNOFF

Streamflow data from basins on the mainland of the Northwest Territories were analyzed to provide an understanding of regional trends in mean annual flow, and to provide a means of estimating it at ungauged locations. Described in this section are

- the procedures used to adjust the data to a common base period
- the regional climatic factors used to assist in drawing a map showing isolines of mean annual runoff for the base period
- an assessment of the year-to-year variability of annual flows
- procedures for estimating mean annual flows for an ungauged location.

4.1 - Mean Annual Runoff

4.1.1 - Data Extension

To provide a consistent time base for the computation of mean annual runoff, the data of some stream gauging stations were extended by correlation with stations having a longer record. It is evident from Plate 9 that 1962 is the earliest date to which all records might be extended. Prior to this date, there were insufficient operational gauging stations.

In the 1976 study a number of techniques for extending the mean annual flow data were considered. The Langbein correlation gave the least residual scatter and was adopted for extending the data. In this study it was again decided that Langbein correlation was most appropriate. This method is described below in detail.

The Langbein method of extending flow records is applied to monthly data which are subsequently averaged to produce mean annual flows (Reference 4). The equation for the relationship is

$$\log X_1 - \overline{\log X_1} = K\,(\log X_2 - \overline{\log X_2}) \qquad \ldots\ (4\text{-}1)$$

where

X_1 is the flow at Station 1 in a particular month

$\overline{\log X_1}$ is the mean of the logs of the flows at Station 1 for the same month

X_2 is the flow at Station 2 for the same month

$\overline{\log X_2}$ is the mean of the logs of the flows at Station 2 for the same month

K is a constant valid for all 12 months of the year.

The equation shows that the correlation is made using logarithmic tranformations, and relates the deviations of the monthly log flows from their monthly log means at the dependent station to the concurrent deviations at the independent station.

Important features of the Langbein procedure are as follows.

- The use of the logarithms of the data removes most of the skewness inherent in the river flow data.

- The relationship derived describes the variation of monthly log flows about the monthly log mean. Therefore, the regression equation statistics (R^2 and Standard Error) cannot be compared directly with similar statistics calculated for simple regression relationships.

- In extending monthly data and averaging the twelve predicted values to obtain the mean annual flow, errors tend to be averaged out over the year.

With Equation 4-1 rewritten as a predictive equation

$$X_1 = 10^{[K(\log X_2 - \overline{\log X_2}) + \overline{\log X_1}]} \quad \ldots\ (4\text{-}2)$$

the monthly data for a dependent Station 1 can be extended to the limit of the monthly data available at an independent Station 2.

In this study, the following guidelines are used in selecting stations to be correlated.

- The stations are located in physiographically and climatically similar areas.

- Basins are as near the same size as possible.

- The period of concurrent records must be greater than 5 years. (Thus, the record for any station with 5 or fewer years of data is not extended.)

A number of correlations were tried for each station. The relationships with the highest correlation coefficients and lowest errors between observed and estimated data were selected for extending the period of record. Table A-1 in the appendix gives a summary of the equations resulting from the analysis and the associated correlation statistics. Table A-2 in the appendix gives the mean monthly flows for the extended period of record, 1962 to 1980.

In general, the results of the analysis are good. The percent error between estimated and observed values, quoted in Table A-1, is based on the monthly flow estimates. The error for estimates of mean annual flow data over the period of overlap is consistently less than 10 percent. Plate 9 shows the period of these data extensions. All possible combinations of correlations were attempted and for periods where no extension is shown, no satisfactory estimate was found.

In cases where a good correlation could not be obtained, an estimate of mean annual runoff was made from actual data, without adjustment. An examination of the long-term mean annual flow with and without data extension indicated that the differences were minor. It is therefore recommended that in future updates of

this work the correlations should only be revised where the period of overlap for previous studies was less than 7 years.

4.1.2 - Construction of Runoff Map

The mean annual runoff in millimetres was computed for each station for the base period of record, 1962 to 1980. These values were plotted on a map at the centroid of each catchment. The centroid was used since the computed runoff represents an average for the entire catchment.

Assistance in the construction of isolines of runoff was derived from known trends in mean annual precipitation and evaporation.

Mean Annual Precipitation

Runoff is proportional to precipitation, and more directly so in northern areas where evaporation losses are lower than in southern areas. Isohyetal maps covering the base period 1962 to 1980 were therefore prepared to assist in the construction of the runoff map for the same period. The precipitation maps were drawn using mean annual data from meteorological stations in the Northwest Territories, and northern Quebec, Manitoba, Saskatchewan and Alberta. The data used are summarized in Table A-3 of the appendix. Precipitation at higher elevations in the Mackenzie Mountains and on Baffin Island was estimated from the precipitation observed at low-level stations using the technique suggested by Burns (Reference 5).

The precipitation maps are presented on Plates 3 and 4 for the Northwest Territories mainland and Arctic Islands, respectively.

Meteorological data in the Northwest Territories have been collected over a longer period than runoff data. To take advantage of the longer meteorological record to estimate long-term runoff, mean annual precipitation maps for the period 1941 to 1980 were also prepared. The data are available in the AES summary publication for the period 1941 to 1970 (Reference 6), augmented by their monthly summaries for the period 1970 to 1980. The maps are presented on Plates 1 and 2 for mainland and Arctic Islands areas, respectively. The data used in map preparation are summarized in Table A-3.

The isohyetal maps presented as Plates 1 to 4 are similar to those presented in the 1976 study. The differences are minor and consist of only small relocations of the isolines.

Annual Evapotranspiration

Average annual lake evaporation, an indicator of potential evapotranspiration, is estimated to vary from almost zero in the northern Arctic Islands to about 40 mm near the Sixtieth Parallel (Reference 7). In areas where water availability is high--where there are large areas covered by lakes, or where vegetation draws heavily on water stored in soil--actual evaporative losses can approach potential losses. In areas where water runs off quickly, actual losses will be much less than potential losses.

The factors influencing the relationship between actual and potential losses in the north are the type of vegetation and soils in the watershed and the amount of surface lake storage relative to the total drainage area. The latter can vary from zero in some areas to more than 30 percent of total drainage area in some Shield basins. Thus, actual losses can be expected to be a high percentage of potential losses in regions with extensive lake storage (e.g., the Canadian Shield Region), or areas with significant transpiration capability. The latter can be expected to increase significantly as the tree line is crossed from northeast to southwest (see Plate 10).

Using the calculated runoff for the base period, and guided by the information on annual precipitation and evaporation, the isolines of mean annual runoff were drawn (see Plate 12). The following points should be noted with respect to the map prepared for the 1962 to 1980 base period.

- The longer period of record provides data which are more reliable in remote areas than data in the 1976 study.

- Runoff increases in a southerly direction since precipitation is increasing and losses remain small. As the density of trees increases toward the tree line, losses increase and runoff gradually decreases.

- The runoff in the eastern Canadian Shield Region is less variable than it was in the 1976 study with runoff of 180 to 200 mm east of 100° west longitude.

- A major difference from the 1976 study is the swing of isolines northeast in the direction of the major axis of Great Slave Lake. This trend is created principally by data for the Thelon River above Beverly Lake (6JC-2), a gauge which has 7 complete years of data and is thought to be reliable. The low runoff (<100 mm) in this basin could possibly be a precipitation effect which is not adequately reflected in the isohyetal maps. The precipitation gauge network is particularly sparse in this area, and it is recommended that more gauges be installed to obtain a better understanding of the precipitation runoff behavior.

- In the north-central Northwest Territories, the isolines indicate decreasing runoff values toward the north, as do the precipitation isohyets. In the Arctic Islands, losses become very low and runoff is not expected to be significantly different from measured precipitation.

- In the Cordilleran Region, there is a sharp increase in runoff with elevation, corresponding to the increased precipitation. Isolines in this area are very approximate due to the limited data available. Runoff can vary considerably from basin to basin depending largely on slope, orientation, and local variations in elevation.

4.2 - Variability of Annual Runoff

The year-to-year variability of annual runoff is defined by the coefficient of variation of the series of annual flows

computed for each station. The coefficient of variation is the ratio of the standard deviation to the mean of the series of numbers, or

$$C_v = \frac{S}{R} \quad \text{.... (4-3)}$$

where

S = standard deviation of mean annual runoff

R = mean annual runoff

The coefficients calculated for each station are plotted on Plates 13 and 14. Since it can be expected that there will be a strong relationship between the variation in precipitation and the variation in runoff (especially in areas with low losses), the coefficients of variation of mean annual precipitation for the period 1962 to 1980 were also computed at each meteorological station and plotted on Plates 13 and 14.

An attempt was made to correlate the coefficients of variation with physiographic and climatic characteristics (see Section 5.2) of each basin. The analysis was performed for data within each physiographic region and no significant relationships were found.

The following points are illustrated by this map.

- Although there is no distinct pattern in the runoff coefficient of variation, the values south of the tree line (0.06 to 0.65) are generally larger than values north of the tree line (0.06 to 0.34). This appears logical, since losses north of the tree line are relatively low, therefore making

runoff less dependent on year-to-year temperature fluctuations. South of the tree line, losses (and therefore runoff) vary more with fluctuations in temperature.

- Although there is no apparent direct relationship between the coefficients of variation of precipitation and runoff in the mainland area, they are in the same range (0.20 to 0.40). In the extreme northern mainland and Arctic Islands, runoff data are nonexistent. However, actual precipitation and runoff are essentially equal and therefore, the variability of precipitation can be used to represent the variability of runoff. Thus, the variability of runoff in the Arctic Islands is 0.20 to 0.40 as noted by the range of precipitation coefficients.

4.3 - Estimates for Ungauged Basins

The maps of mean annual runoff and coefficients of variation can be used to estimate the same variables for ungauged drainage basins by carrying out the following steps.

(a) Delineate and measure the area of the drainage basin being considered.

(b) Plot the drainage basin and its centroid on the map of mean annual runoff (Plate 12). Determine the mean annual runoff in millimetres at the centroid of the basin by interpolating between isolines.

If the basin under consideration is located on the Arctic Islands, use the map of mean annual precipitation (Plates 2 and 4). The estimate obtained from this map can be adjusted upward or downward if local knowledge is available regarding redistribution of snow into or out

of the basin. If local knowledge is not available, the precipitation should be increased by 50 percent to account for differences between gauge and actual precipitation (Reference 3).

(c) Compute the mean annual discharge in cubic metres per second as follows

$$\overline{Q} = 0.00003171\ RA \qquad \ldots\ (4\text{-}4)$$

where

$\overline{Q}$ = mean annual discharge (m^3/s)

R = mean annual runoff (mm)

A = drainage area (km^2)

(d) To determine the variability of the estimated mean annual discharge, a coefficient of variation is estimated from Plates 13 and 14, using the following guidelines.

- On the mainland south of the Arctic Circle, the coefficient should be estimated as follows.

  If the drainage basin is geographically close (say, within 200 km) to a gauged basin with a recorded coefficient of variation, the recorded value can be used if the two basins have similar drainage areas and physiographic characteristics.

If the drainage basin is remote from a gauged basin, a high degree of judgment is required. If no other data are available, use the following average values for each region.

Cordilleran Region - 0.18

Interior Plains Region - 0.41

Canadian Shield Region - 0.24

The coefficient may be decreased if a degree of over year flood storage is suspected.

- North of the Arctic Circle, the coefficient should be determined as follows.

  If the drainage basin is geographically close to a meteorological station (say, within 200 km) and has the same degree of exposure to storms originating over water, then the coefficient of variation for the meteorological station should be used.

  If the basin is protected from the direct influence of weather systems originating over water, a coefficient of 0.30 should be used. In more exposed locations, this value should be increased to 0.40.

The standard deviation of the mean annual discharge in cubic metres per second is computed from the coefficient of variation using the equation

$$S = C_v \overline{Q} \qquad \ldots\ (4\text{-}5)$$

The statistical interpretation of the standard deviation for a lognormally distributed population is that the mean discharge in any 1 year will lie between

$$\overline{Q} + K_l \, S$$

$$\overline{Q} + K_u \, S$$

In these equations, K_l and K_u are coefficients which vary with the coefficient of variation, C_v, and the desired confidence limit. Figure 4.1 gives values of K_u and K_l for confidence limits of 60, 80, 90, 95 and 99 percent with C_v ranging from 0.0 to 0.7.

(e) The estimate of mean annual runoff computed in Step (c) is for a base period of 1962 to 1980. To adjust this estimate to the base period of the long-term meteorological record (1941 to 1980), estimates of mean annual precipitation for each period should be obtained from the precipitation maps (Plates 1 to 4). This is done by plotting the centroid of the basin on the maps and interpolating between isohyets.

The 1962 to 1980 base period runoff can be adjusted by the ratio of the 1941 to 1980 precipitation to the 1962 to 1980 precipitation.

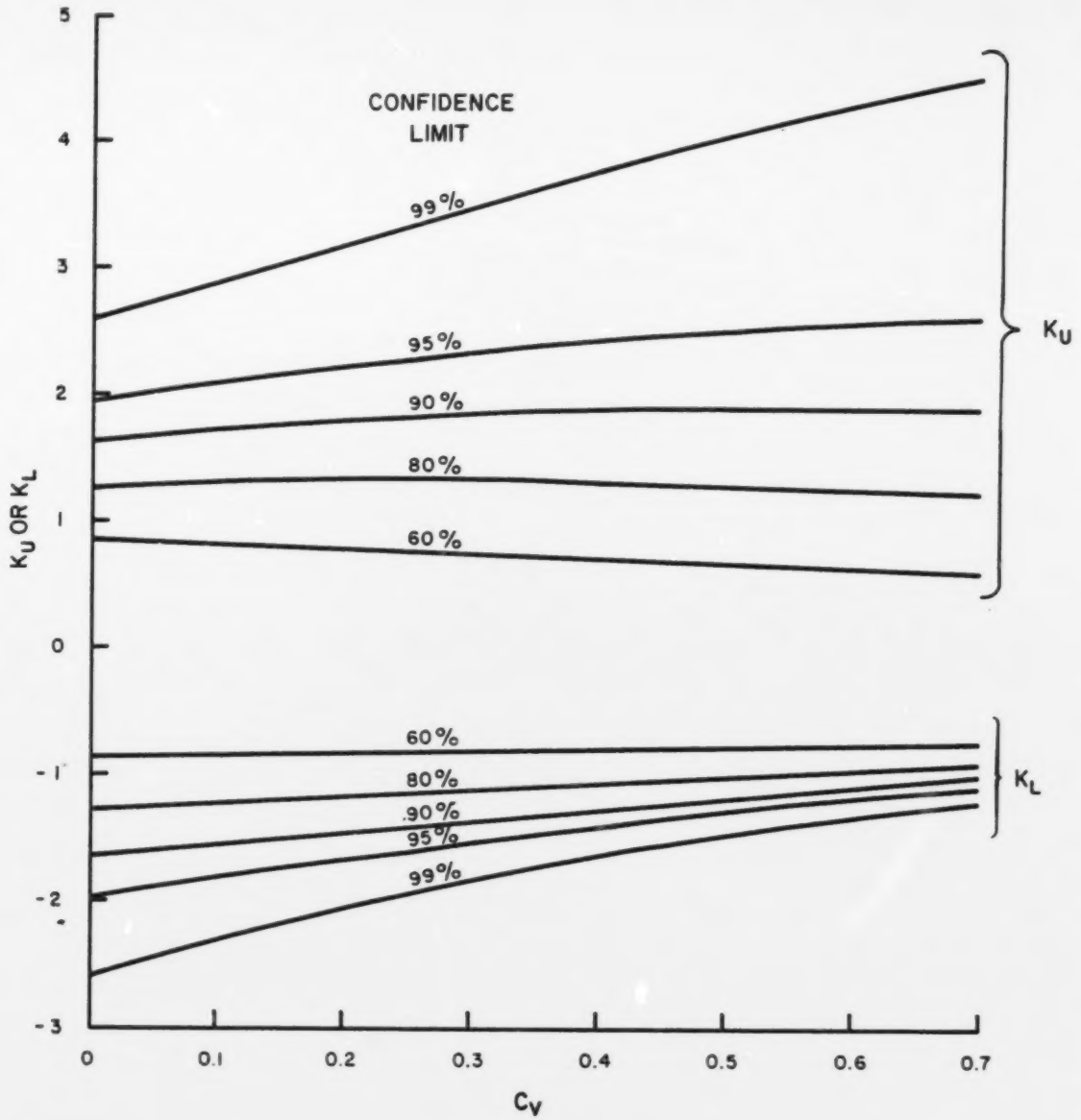
$$R_{41-80} = R_{62-80} \, \frac{P_{41-80}}{P_{62-80}} \qquad \ldots\ (4\text{-}6)$$

where

R_{41-80} = 1941 to 1980 base period mean annual runoff

R_{62-80} = 1962 to 1980 base period mean annual runoff

P_{41-80} = 1941 to 1980 base period mean annual precipitation



NOTE: BASED ON WORK OF V. T. CHOW (REFERENCE 9)

FIG. 4.1

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

VALUES OF K_U AND K_L FOR VARIABILITY OF MEAN ANNUAL DISCHARGE

AGRA

P_{62-80} = 1962 to 1980 base period mean annual precipitation.

4.4 - Example Calculations

4.4.1 - Arctic Red River Near the Mouth (10LA-2)

Step (a) Drainage area = 15 100 km^2

Step (b) Locate centroid of basin and estimate mean annual runoff from Plate 12 = 320 mm.

Step (c) Use Equation 4-4.

$$\overline{Q} = 0.00003171 \times 320 \text{ mm} \times 15\,100 \text{ km}^2$$
$$= 153 \text{ m}^3/\text{s}$$

Step (d) Estimate coefficient of variation from Plate 13.

Choose C_v = 0.18 (Cordilleran Region).

Calculate S from Equation 4-5.

$S = 0.18 \times 153 \text{ m}^3/\text{s} = 27.6 \text{ m}^3/\text{s}$

Determine K_l and K_u from Figure 4.1 for 95 percent confidence limits.

$K_l = -1.70$

$K_u = 2.20$

Therefore there is a 95 percent chance that the mean annual runoff in any year will fall between 106 and 214 m^3/s.

4.4.2 - Liard River Near the Mouth (10ED-2)

Step (a) Drainage area = 277 000 km^2

Step (b) Mean annual runoff = 275 mm (Plate 12)

Step (c) $\overline{Q}$ = 0.00003171 x 275 mm x 277 000 km^2
= 2,415 m^3/s

Step (d) Choose C_v = 0.18 (close to 10ED-1 with C_v = 0.18)

S = 0.18 x 2,415 m^3/s = 435 m^3/s

K_1 = -1.70

K_u = 2.20

Therefore there is a 95 percent change that the mean annual runoff in any year will fall between 1,680 and 3,370 m^3/s.

4.4.3 - Willowlake River Near the Mouth (10GB-1)

Step (a) Drainage area = 21 600 km^2

Step (b) Mean annual runoff = 80 mm (Plate 12)

Step (c) $\overline{Q}$ = 0.00003171 x 80 mm x 21 600 km^2
= 55 m^3/s

Step (d) Choose C_v = 0.25 (close to 10JB-1 with C_v = 0.25)

$S = 0.25 \times 55\ m^3/s = 14\ m^3/s$

$K_l = -1.60$

$K_u = 2.25$

Therefore, there is a 95 percent chance that the mean annual runoff in any year will fall between 33 and 87 m^3/s.

Step (e) $Q_{41-80} = (55\ m^3/s)\frac{310\ mm\ (Plate\ 1)}{285\ mm\ (Plate\ 3)} = 60\ m^3/s$

4.4.4 - Taltson River Above Porter Lake Outflow (7QD-4)

Step (a) Drainage area = 12 800 km^2

Step (b) Mean annual runoff = 100 mm (Plate 12) - 1962 to 1980

Step (c) $\overline{Q} = 0.00003171 \times 100\ mm \times 12\ 800\ km^2$
$= 41\ m^3/s$

Step (d) Choose C_v = 0.24 (close to 7QC-3 with C_v = 0.24)

$S = 0.24 \times 41\ m^3/s = 10\ m^3/s$

$K_l = -1.65$

$K_u = 2.25$

Therefore there is a 95 percent chance that the mean annual runoff in any year will fall between 25 and 63 m^3/s.

Step (e) $Q_{41-80} = (41\ m^3/s)\frac{275\ mm\ \text{(Plate 1)}}{275\ mm\ \text{(Plate 3)}} = 41\ m^3/s)$

5 - LOW FLOWS

As discussed in Section 3.2, flows in gauged basins in the Northwest Territories consistently reach an annual low at the end of the long, cold winter. Low flows resulting from lack of summer rainfall are not evident in the available records--probably due to the generally large size of the gauged basins.

Low flow frequency curves were developed for 32 rivers in the Northwest Territories from data published by the Water Survey of Canada. There is substantially more data available in this study than in the 1976 study and, therefore, it is possible to estimate low flow with more confidence. Relationships between the characteristics of these frequency curves and physiographic and climatic parameters are the basis for estimates of low flow at ungauged locations. There are substantial changes in these relationships from those presented in 1976. These changes are due primarily to the longer period of record and the greater number of stations.

This section contains a discussion of

- the approaches tried
- the equations adopted
- the limits of applicability of the equations.

5.1 - Low Flow Characteristics

Sufficient published data are available for analysis of low flows at 38 unregulated gauges on the mainland. Of these basins, 11 are located in the Cordillera, 12 in the Interior Plains, and 15 in the Canadian Shield.

Low flow data were compiled for 11 Cordilleran basins, 12 Interior Plains basins and 15 Canadian Shield basins. The Interior Plains Region has 3 basins, which are always zero low flow, and the Canadian Shield Region also has 3 basins which always have zero low flow. These cases do not require frequency analysis. Lognormal frequency curves for the 11 Cordilleran basins, 9 Interior Plains basins and 12 Canadian Shield basins are presented on Plates 15, 16 and 17.

Based on the results of the 1976 study, the 30-day low flow (Q_{30}) was determined for each year of record. The previous study found that low flows for durations of less than 30 days had values which were very close to Q_{30}. The 30-day low flow is the lowest average flow over a 30-day period in a calendar year. For simplicity of computational analysis the monthly flows were examined and if 2 months had close to the same low flow (within 10 percent), the monthly low flow was taken as Q_{30}. If the 2 lowest months varied significantly the daily records were used to obtain Q_{30}.

Frequency analysis was performed on the data for each gauge, and flows corresponding to return periods of 5, 10 and 20 years were calculated. The mean 30-day low flow, Q_{30} for the period of record of each station was also calculated. Lognormal frequency curves are presented on Plates 15, 16 and 17 for each region.

5.2 - Analysis of Regional Trends

To provide a basis for estimating low flow characteristics of ungauged basins, easily determined physiographic and climatic parameters were chosen as independent variables and used in multiple linear regression analysis to develop prediction equations.

5.2.1 - Physiographic Characteristics

All physiographic data were measured using 1:500 000-scale National Topographic System maps published by the Surveys and Mapping Branch of the Department of Energy, Mines and Resources. It was found that these maps are inconsistent in the detail shown and care must be used in extracting data such as the area of lakes. These discrepancies occur primarily in the northern Interior Plains where many small lakes exist but are not always mapped. The use of larger scale maps could greatly improve the accuracy of measured physiographic characteristics.

Total Basin Area - A_B - The total basin area tributary to each stream gauge is published by the Water Survey of Canada.

Stream Length - L_B - This length is the distance along the stream from the gauge to a point on the main stem of the channel which drains 5 percent of the basin.

Stream Slope - S_S - The stream slope is defined as the difference in elevation between the gauge and a point on the stream which drains 5 percent of the drainage area, divided by the stream length, L_B. In cases where exact elevations were not available, slope was estimated from elevation contours crossing the stream.

Proportion of Lake Area - The on-channel lake ratio (A_{ON}) is the proportion of total basin area occupied by lakes that lie on the main stem of the river. The off-channel lake ratio (A_{OFF}) is the

proportion of basin area (excluding the on-channel lake area) occupied by lakes that do not lie on channel. The total lake area ratio (A_{TOT}) is the proportion of total basin area occupied by all lakes. Rather than using conventional planimetering or dot-counting methods to estimate lake areas, a random-dot overlay sheet (an application of the Monte Carlo random selection principle) was used. Dot counts were made several times and averaged for more accurate results.

5.2.2 - Climatic Characteristics

The climatic parameters chosen for inclusion in the analysis are

- annual mean daily temperature, T_{MA}
- February mean daily temperature, T_{FEB}
- annual total precipitation, P_{MA}

T_{MA} and T_{FEB} at the basin centroids are estimated from Canada Department of Transport, Meteorological Branch, climatic maps, derived for a base period of 1931 to 1960 (Reference 7). These maps are reproduced on Plates 5 and 6 respectively.

Mean annual precipitation is determined at the basin centroids by interpolation between isohyets on Plate 3.

The physiographic and climatic data extracted for each gauged catchment are summarized in Table A-4.

5.2.3 - Method of Analysis

The object of regional analysis was to develop techniques for the prediction of low flow (Q_{30}) for

various return periods. The previous 1976 study attempted the analysis by 2 approaches:

- an approach similar to the Index Flood Method which is also called the Dalrymple Method (Reference 8)

- direct regression for specific return periods.

The first technique was not at all successful in the previous study and, consequently, was not attempted in this work. The approach used in this current analysis was to derive prediction equations for the mean 5-, 10- and 20-year, 30-day low flows by direct regression with climatic and physiographic parameters for each basin within a hydrologically homogeneous region. The analysis was performed using a multiple linear regression computer program. The backward deletion process was employed, using the F-statistic at the 90 percent confidence level as the criterion of acceptance of independent variables into the predictive equation. Two types of regression equations were explored.

Linear $$Y = a + bX_1 + cX_2 \quad \ldots\ (5\text{-}1)$$

Power Law $$Y = aX_1^{\,b}\, X_2^{\,c} \quad \ldots\ (5\text{-}2)$$

The dependent variable Y is the 30-day low flow, Q_{30}.

5.2.4 - Results of Analysis

The basins were classified according to region (Cordillera, Interior Plains, or Canadian Shield) and each region was analyzed separately.

Cordilleran Region

The 11 basins in this region used in the analysis are listed in Table 5-1.

The best relationship is of the form

$$(Q_{30})_T = a_T \, (Q_{MA})^{b_T} \ (m^3/s) \qquad \ldots\ldots (5\text{-}3)$$

where a_T and b_T are constants for specific return periods T.

Values of a_T and b_T, summarized in Table 5-4, allow the prediction of the mean 5-, 10- and 20-year low flows.

The relationships found are similar to those found in the 1976 study except the power of mean annual flow is no longer.

Interior Plains Region

The 10 basins in this region which were used in the analysis are listed in Table 5-2. The three basins which always have zero low flows are included.

The Great Bear River (10JC-3) was not included in the analysis because its large amount of lake storage creates natural regulation that is not homogeneous with the rest of the region.

TABLE 5-1

CORDILLERAN STATIONS USED FOR LOW FLOW ANALYSIS

WSC Station Number	River Name
9FD-1	Porcupine at Old Crow
10MA-1	Peel above Canyon Creek
10MC-2	Peel above Fort McPherson
9BB-1	South MacMillan at Canol
10EA-3	Flat near the mouth
10EB-1	South Nahanni above Virginia Falls
10EC-1	South Nahanni above Clausen Creek
10GA-1	Root near the mouth
10LA-2	Arctic Red near the mouth
10ED-1	Liard at Fort Liard
10ED-2	Liard near the mouth

TABLE 5-2

INTERIOR PLAINS STATIONS
USED FOR LOW FLOW ANALYSIS

WSC Station Number	River Name
10LC-3	Rengleng below Dempster Highway
10LC-7	Caribou Creek above Dempster Highway
10JB-1	Johnny Hoe above Lac Ste. Therese
10GB-1	Willowlake near the mouth
10GC-2	Harris near the mouth
10GC-3	Martin near the mouth
10FB-5	Jean-Marie at Fort Simpson Highway
10FA-2	Trout at Fort Simpson Highway
7UC-1	Kakisa at outlet of Kakisa Lake
7OB-1	Hay near Hay River

The Buffalo River (7PA-1) was not included in the analysis because it was an obvious outlier in attempted regressions. The basin is relatively large with a drainage area of 17 800 km^2, however, the annual low flow reached zero in 8 out of 12 years. The river drains from the Caribou Mountains through a large lake with a small flat outlet that routinely freezes to the thalweg, thus effectively damming off any discharge.

For the balance of the river basins, the best relationship is of the form

$$(Q_{30})_T = a_T \, (Q_{MA})^{b_T} \ (m^3/s) \qquad \ldots\ (5\text{-}4)$$

where a_T and b_T are constants for specific return periods T.

Values of a_T and b_T are summarized in Table 5-4.

The relationships found differ from those found in the 1976 study. In the previous study, Great Bear River was included in the analysis. The large lake area in this basin dominated the regression equations which were based on data from only 4 stations. The current relationships have coefficients of correlation which are lower, however, the equations give more reliable predictions.

Canadian Shield Region

The 15 basins in this region which were used in the analysis are listed in Table 5-3. The three basins which always have zero low flow are included.

TABLE 5-3

CANADIAN SHIELD STATIONS USED FOR LOW FLOW ANALYSIS

WSC Station Number	River Name
7QC-3	Thoa near inlet to Hill Island Lake
7SB-9	Baker Creek main stem near Yellowknife
7RD-1	Lockhart at outlet of Artillery Lake
10JA-2	Camsell at outlet of Clut Lake
10PB-1	Coppermine at outlet of Point Lake
10QA-1	Tree near the mouth
10RC-1	Back below Deep Rose Lake
6JC-2	Thelon above Beverly Lake
6MA-3	Thelon above Baker Lake
6KC-3	Dubawnt below Marjorie Lake
6LA-1	Kazan at outlet at Ennadai Lake
6LC-1	Kazan above Kazan Falls
6MA-2	Kingyouk Creek near Baker Lake
6MB-1	Quoich above St. Clair Falls
10SB-1	Hayes above Chantrey Inlet

TABLE 5-4

LOW FLOW REGRESSION EQUATION SUMMARY

Cordilleran Region

Return Period	Regression Equation	R^2	Equation Number
Mean Annual	$\bar{Q}_{30} = 0.0372\ Q_{MA}^{1.160}$	0.95	5 - 3 (a)
5 year	$Q_{30(5)} = 0.0155\ Q_{MA}^{1.266}$	0.95	5 - 3 (b)
10 year	$Q_{30(10)} = 0.0123\ Q_{MA}^{1.287}$	0.94	5 - 3 (c)
20 year	$Q_{30(20)} = 0.00936\ Q_{MA}^{1.315}$	0.93	5 - 3 (d)

Range of Input Data: $997\ km^2 < A < 277\ 000\ km^2$; $21\ m^3/s < Q_{MA} < 2\ 440\ m^3/s$

Interior Plains Region

Return Period	Regression Equation	R^2	Equation Number
Mean Annual	$\bar{Q}_{30} = 9.23 \times 10^{-4}\ Q_{MA}^{2.004}$	0.79	5 - 4 (a)
5 year	$Q_{30(5)} = 7.28 \times 10^{-4}\ Q_{MA}^{1.853}$	0.76	5 - 4 (b)
10 year	$Q_{30(10)} = 4.55 \times 10^{-4}\ Q_{MA}^{1.861}$	0.71	5 - 4 (c)
20 year	$Q_{30(20)} = 4.58 \times 10^{-4}\ Q_{MA}^{1.799}$	0.70	5 - 4 (d)

Range of Input Data: $570\ km^2 < A < 47\ 900\ km^2$; $1.03\ m^3/s < Q_{MA} < 106\ m^3/s$

Table 5-4
Low Flow Regression Equation Summary - 2

Canadian Shield Region

Return Period	Regression Equation	R^2	Equation Number
Mean Annual	$\overline{Q}_{30} = 1.88\times10^{-4}\ Q_{MA}^{1.694}\ A_{TOT}^{2.946}\ (T_{FEB}+37)^{3.963}$	0.96	5 -5 (a)
5 year	$Q_{30(5)} = 6.37\times10^{-5}\ Q_{MA}^{1.669}\ A_{TOT}^{2.539}\ (T_{FEB}+37)^{4.154}$	0.96	5 -5 (b)
10 year	$Q_{30(10)} = 4.48\times10^{-5}\ Q_{MA}^{1.655}\ A_{TOT}^{2.405}\ (T_{FEB}+37)^{4.207}$	0.96	5 -5 (c)
20 year	$Q_{30(20)} = 3.35\times10^{-5}\ Q_{MA}^{1.643}\ A_{TOT}^{2.292}\ (T_{FEB}+37)^{4.249}$	0.96	5 -5 (d)

Range of Input Data: $433\ km^2 < A < 154\ 000\ km^2$; $2.49\ m^3/s < Q_{MA} < 757\ m^3/s$; $0.103 < A_{TOT} < 0.333$; $-35.5^oC < T_{FEB} < -25.0^oC$

LEGEND

$\overline{Q}_{30}$	- mean annual 30-day low flow (m^3/s)
$Q_{30(5)}$, $Q_{30(10)}$, $Q_{30(20)}$	- 30-d low flows with return periods of 5-, 10- and 20-years respectively (m^3/s)
Q_{MA}	- mean annual flow (m^3/s)
A_{TOT}	- proportion of drainage area covered with lakes
A	- drainage area (km^2)
T_{FEB}	- February mean daily temperature (^oC)
R^2	- coefficient of determination of regression equation

Regression analysis of data from these stations results in equations of the form

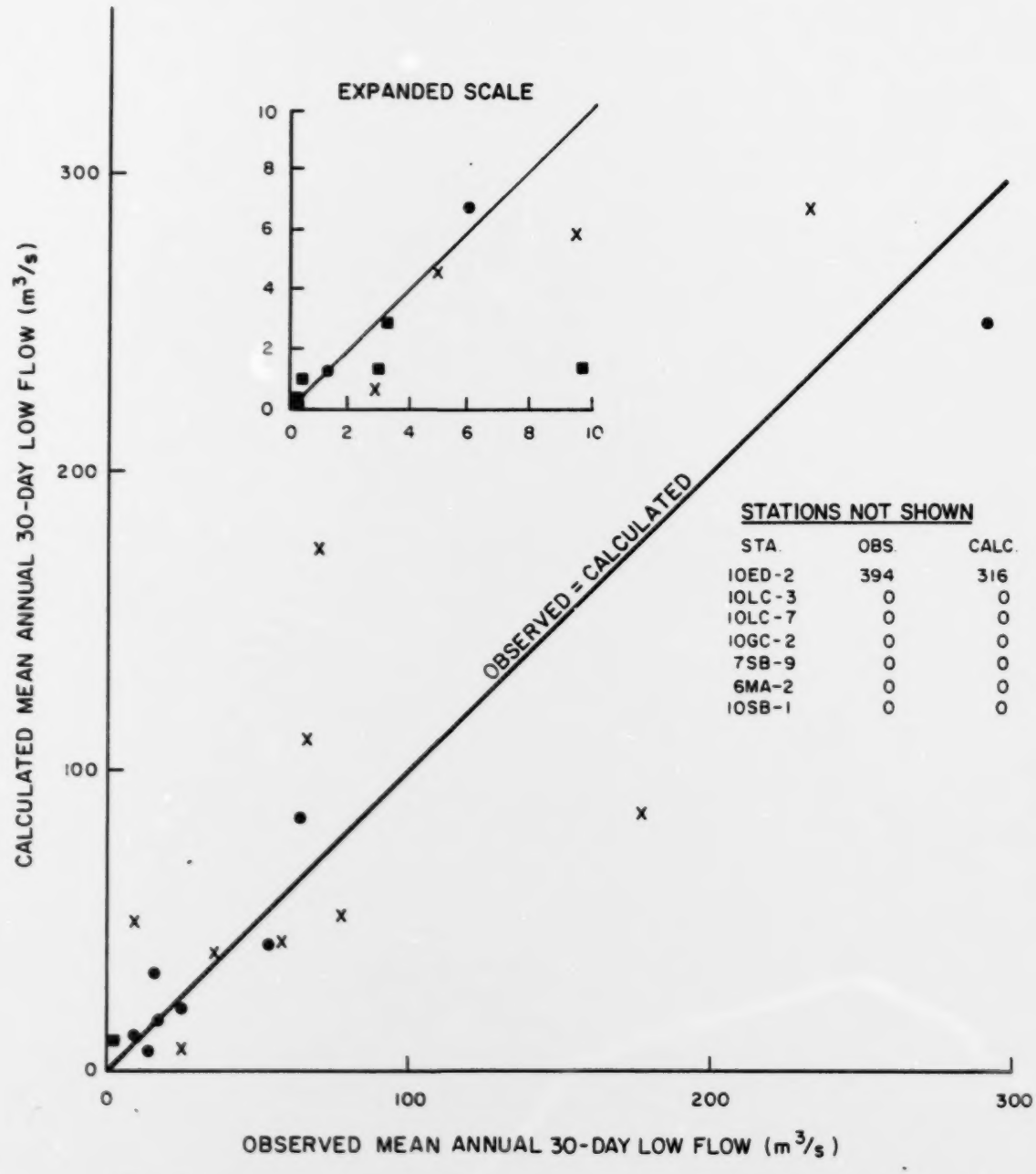
$$(Q_{30})_T = a_T \, Q_{MA}^{\,b_T} \, A_{TOT}^{\,c_T} \, (T_{FEB}+37)^{d_T} \; (m^3/s) \quad .... \quad (5\text{-}5)$$

The coefficients a_T, b_T, c_T and d_T are presented in Table 5-4. The number 37 is approximately the absolute value of the lowest expected value for T_{FEB} in the region. The range of $(T_{FEB}+37)$ is therefore approximately 1 to 36°C.

The current relationships are of a power law form as opposed to the linear form presented in the 1976 study. The current relationships, however, use the same basic physiographic and climatic parameters. The proportion of lake area is used instead of the basin slope, but this is still consistent because the two parameters are inversely related. The current relationships have coefficients of correlation which are significantly greater than those found in the 1976 study.

Figure 5.1 shows predicted versus observed mean annual 30-day low flows. The equations consistently predict zero flow in the Interior Plains and Canadian Shield regions. The scatter about the line of equivalence is large in some cases, however, no consistent high or low bias is built into the equations.

It should be noted that the equations become progressively poorer predictors as the return period increases. More reliability can, therefore, be placed on the prediction of the mean annual 30-day low flow than on the prediction of the 20-year low flow.



STATIONS NOT SHOWN

STA.	OBS.	CALC.
10ED-2	394	316
10LC-3	0	0
10LC-7	0	0
10GC-2	0	0
7SB-9	0	0
6MA-2	0	0
10SB-1	0	0

LEGEND

- ● - CORDILLERAN REGION
- ■ - INTERIOR PLAINS REGION
- X CANADIAN SHIELD REGION

FIG 5.1

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

MEAN ANNUAL 30-DAY LOW FLOW – COMPARISON OF OBSERVED AND CALCULATED VALUES

ACRES

5.2.5 - Comments on the Results

The regionalization of low flow data from the gauged river basins gives two forms of relationship for the prediction of each of the mean 5-, 10- and 20-year, 30-day low flows. The prediction equations for the Cordilleran and the Interior Plains regions are in a simple power law relationship with mean annual discharge. The prediction equations for the Canadian Shield Region are in a power law relationship with mean annual discharge, proportion of lake area, and mean daily February temperature.

The equations derived from regression analysis are consistent with the physical characteristics of northern hydrology. A larger amount of surface storage maintains low flows at relatively higher levels because of natural regulation. A lower February mean daily temperature causes an increase in channel restriction by ice, and larger volumes of water are stored in the form of ice--both factors leading to lower low flows.

The differences from the 1976 study are the following.

- The prediction equations for the Cordilleran and Interior Plains regions are in a power law relationship with mean annual discharge, Q_{MA}. The power of Q_{MA} is now greater than unity.

- The Interior Plains relationship no longer includes the proportion of lake area--a physiographic parameter which was included in the 1976 study because of the area of Great Bear Lake.

- The equations for the Canadian Shield Region are power law relationships as opposed to the previous linear form. The proportion of basin area occupied by lakes was also found to be more signifiant than basin slope.

- The relationships are developed on a much better data base than was available in the 1976 study and greater confidence can be placed in them.

The current relationships are suitable for preliminary feasibility purposes, but should be confirmed by detailed hydrologic analysis for engineering purposes. If the many gauges that were installed in the past several years are maintained in the future, it should be possible to derive new relationships that are significantly improved. It is also possible that data from these gauges will allow future subdivision into smaller subregions.

5.3 - Application to Ungauged Basins

To use the predictive relationships for the mean 5-, 10- and 20-year low flows in an ungauged basin, the following steps should be carried out.

(a) Determine whether the basin lies within the Cordilleran, Plains or Shield physiographic regions. These regions are delineated on Plate 10. Delineate and measure the area of the drainage basin being considered.

(b) Determine the mean annual flow as outlined in Section 4.3.

(c) Compute the low flow

- If the ungauged basin is in the Cordilleran Region or Interior Plains Region, go directly to Table 5-4 and use Equations 5-3 (a) to (d) or 5-4 (a) to (d) to estimate the mean 5-, 10- and 20-year low flows. If the calculated value of Q_{MA} is outside the range of values used to establish the original relationship (see Table 5-4), use the equation with caution.

- If the ungauged basin is in the Canadian Shield Region, measure the proportion of lake area A_{TOT} as outlined in Section 5.2.1, determine the February mean daily temperature at the basin centroid from Plate 6 and apply Equation 5-5 (a) to (d) from Table 5-4. Again, if either of the independent variables is outside the range of variables used to establish the original relationship (see Table 5-4), use the equation with caution.

5.4 - Example Calculations

5.4.1 - Arctic Red River Near the Mouth (10LA-2)

Step (a) Basin lies within the Cordilleran Region

Drainage area = 15 100 km^2

Step (b) Mean annual runoff from Plate 12 = 320 mm
Mean annual flow is computed from Equation 4-4

Q_{MA} = 0.00003171 x 320 mm x 15 100 km^2
= 153 m^3/s

Step (c) From Table 5-4 the low flows are estimated

$$\overline{Q}_{30} = 0.0372\ Q_{MA}^{1.160} = 12.7\ m^3/s$$

$$Q_{30(5)} = 0.0155\ Q_{MA}^{1.266} = 9.0\ m^3/s$$

$$Q_{30(10)} = 0.0123\ Q_{MA}^{1.287} = 8.0\ m^3/s$$

$$Q_{30(20)} = 0.00936\ Q_{MA}^{1.315} = 7.0\ m^3/s$$

5.4.2 - Liard River Near the Mouth (10ED-2)

Step (a) Basin lies within the Cordilleran Region

Drainage area = 277 000 km^2

Step (b) Mean annual runoff from Plate 12 = 275 mm
Mean annual flow from Equation 4-4

$$Q_{MA} = 0.00003171 \times 275\ mm \times 277\ 000\ km^2$$
$$= 2,415\ m^3/s$$

Step (c) From Table 5-4, the low flows are estimated

$$\overline{Q}_{30} = 0.0372\ Q_{MA}^{1.160} = 312\ m^3/s$$

$$Q_{30(5)} = 0.0155\ Q_{MA}^{1.266} = 297\ m^3/s$$

$$Q_{30(10)} = 0.0123\ Q_{MA}^{1.287} = 278\ m^3/s$$

$$Q_{30(20)} = 0.00936\ Q_{MA}^{1.315} = 263\ m^3/s$$

5.4.3 - Willowlake River Near the Mouth (10GB-1)

Step (a) Basin lies within the Interior Plains Region

Drainage area = 21 600 km^2

Step (b) Mean annual runoff from Plate 12 = 80 mm
Mean annual flow from Equation 4-4

$$Q_{MA} = 0.00003171 \times 80\ mm \times 21\ 600\ km^2$$
$$= 55\ m^3/s$$

Step (c) From Table 5-4 the low flows are estimated

$$\overline{Q}_{30} = 9.23 \times 10^{-4}\ Q_{MA}^{2.004} = 2.8\ m^3/s$$

$$Q_{30(5)} = 7.28 \times 10^{-4}\ Q_{MA}^{1.853} = 1.2\ m^3/s$$

$$Q_{30(10)} = 4.55 \times 10^{-4}\ Q_{MA}^{1.861} = 0.8\ m^3/s$$

$$Q_{30(20)} = 4.58 \times 10^{-4}\ Q_{MA}^{1.799} = 0.6\ m^3/s$$

5.4.4 - Taltson River Above Porter Lake Outflow (7QD-4)

Step (a) Basin lies within the Canadian Shield Region

Drainage area = 12 800 km^2

Step (b) Mean annual runoff from Plate 12 = 100 mm
Mean annual flow from Equation 4-4

$$Q_{MA} = 0.00003171 \times 100 \text{ mm} \times 12\,800 \text{ km}^2$$
$$= 41 \text{ m}^3/\text{s}$$

Step (c) Proportion of lake area in the basin was measured as $A_{TOT} = 0.204$

The February mean daily temperature, T_{FEB} from Plate 6 = -27.0°C

From Table 5-4, the low flows are estimated

$$\overline{Q}_{30} = 1.88\times10^{-4} \; Q_{MA}^{1.694} \; A_{TOT}^{2.946} \; (37+T_{FEB})^{3.963} = 8.6 \text{ m}^3/\text{s}$$

$$Q_{30(5)} = 6.37\times10^{-5} \; Q_{MA}^{1.669} \; A_{TOT}^{2.539} \; (37+T_{FEB})^{4.154} = 7.9 \text{ m}^3/\text{s}$$

$$Q_{30(10)} = 4.48\times10^{-5} \; Q_{MA}^{1.655} \; A_{TOT}^{2.405} \; (37+T_{FEB})^{4.207} = 7.4 \text{ m}^3/\text{s}$$

$$Q_{30(20)} = 3.35\times10^{-5} \; Q_{MA}^{1.643} \; A_{TOT}^{2.292} \; (37+T_{FEB})^{4.249} = 6.9 \text{ m}^3/\text{s}$$

6 - FLOOD FLOWS

Flood frequency curves were developed for 51 rivers in the Northwest Territories from data published by the Water Survey of Canada. Relationships between the characteristics of these frequency curves and physiographic and climatic parameters are the basis for estimates of flood flow at ungauged locations.

This section contains a discussion of

- the approaches tried
- the equations adopted
- the limits of applicability of the equations.

6.1 - Flood Flow Characteristics

Sufficient published data are available for analysis of flood flows at 51 basins. Of these 51 basins, 3 in the Canadian Shield are regulated. These regulated catchments were individually analyzed, but were not included in the regional analysis. Of the 51 basins, 15 are in the Cordilleran, 15 in the Interior Plains, and 21 in the Canadian Shield regions.

The annual peak daily flow, extracted from published records, is used as the indicator of the flood peak. Frequency analysis was performed on data from each station for which there are five or more years of flood data. Freshwater Creek near Cambridge Bay (10TA-1) on Victorian Island in the Arctic Islands was analyzed with 4 years of data and included in the Canadian Shield Region of the mainland. The Kendall River near the outlet of Dismal Lake (10PC-1) was also analyzed for

4 years of data because its addition significantly improved the coverage of the northern Canadian Shield Region.

The log-Pearson Type III distribution (Reference 9) is recommended for flood frequency analysis by the American Society of Civil Engineers. However, it is difficult to estimate the coefficient of skew required to define this distribution unless there are 15 or more years of flood data. There are 14 gauges currently having in excess of 15 years of data. These gauges are listed in Table 6-1. The range of skewness calculated for these rivers using the logs of the flows is approximately 0 to -2.

Negative skewness is a common phenomenon in flood frequency analysis which is caused by a physical attenuation of large flood peaks. This attenuation can be caused by overtopping of river banks with larger flows, storage in on- and off-channel lakes, and channel storage in the river itself. Negative skewness in log data will manifest itself as a plot which is concave downwards on lognormal probability graph paper. Negative skewness of log flows, therefore, results in lower estimates for high return period floods than would occur with zero skew data.

A definite trend toward negative skewness is indicated but was felt to be significant on only 4 of the unregulated basins and 1 regulated basin. The log-Pearson Type III distribution is used for those 4 basins (see Table 6-1) in subsequent regional analyses while the two-parameter log-normal distribution is used for all other basins.

A future update of this report should address negative skewness in greater detail. An additional 5 years of data for many rivers will probably allow regional analysis of

TABLE 6-1

STATIONS USED FOR LOG-PEARSON TYPE III FREQUENCY ANALYSIS

WSC Station Number	River Name
9FD-1*	Porcupine at Old Crow
10EA-3	Flat near the Mouth
10EB-1	South Nahanni above Virginia Falls
10EC-1	South Nahanni above Clausen Creek
10ED-1*	Liard at Fort Liard
10JC-3*	Great Bear at outlet of Great Bear Lake
7UC-1	Kakisa at outlet of Kakisa Lake
7OB-1	Hay near Hay River
7QA-1	Taltson at outlet of Tsu Lake (regulated)
7SB-3*	Yellowknife at inlet to Prosperous Lake (regulated)
7RD-1	Lockhart at outlet of Artillery Lake
10JA-2	Camsell at outlet of Clut Lake
10PB-1*	Coppermine at outlet of Point Lake
10RC-1	Back below Deep Rose Lake

*Stations where the Log-Pearson III distribution was found to be significantly different from the two-parameter lognormal distribution.

skewness. Flood frequency curves are plotted on lognormal probability graphs and presented on Plates 18, 19, 20 and 21.

Table A-5 in the appendix summarizes the flood data calculated for each station.

6.2 - Analysis of Regional Trends

The analysis of regional flood hydrology examined three approaches

- Index Flood Method (or Dalrymple Method)
- Direct Regression Equations
- Frequency Curve Slope Prediction.

The three methods are described below in detail, focusing on the Index Flood Method and the Direct Regression Equations approach. Both of these techniques gave reasonable results but the Index Flood Method is marginally better than the Direct Regression Equations approach.

6.2.1 - Index Flood Method

The Index Flood Method (or Dalrymple Method) has been extensively applied in the United States by the U.S. Geological Survey. It provides a method of calculating a nondimensional flood frequency curve for a hydrologically homogeneous region. The accepted test for basin homogeneity developed by Langbein and published in Dalrymple is that the slope of an individual frequency curve shall be no more at variance with the others in the region than can be explained by errors in sampling (Reference 8). Figures 6.1, 6.2 and 6.3 show the nondimensional frequency curves for the three mainland

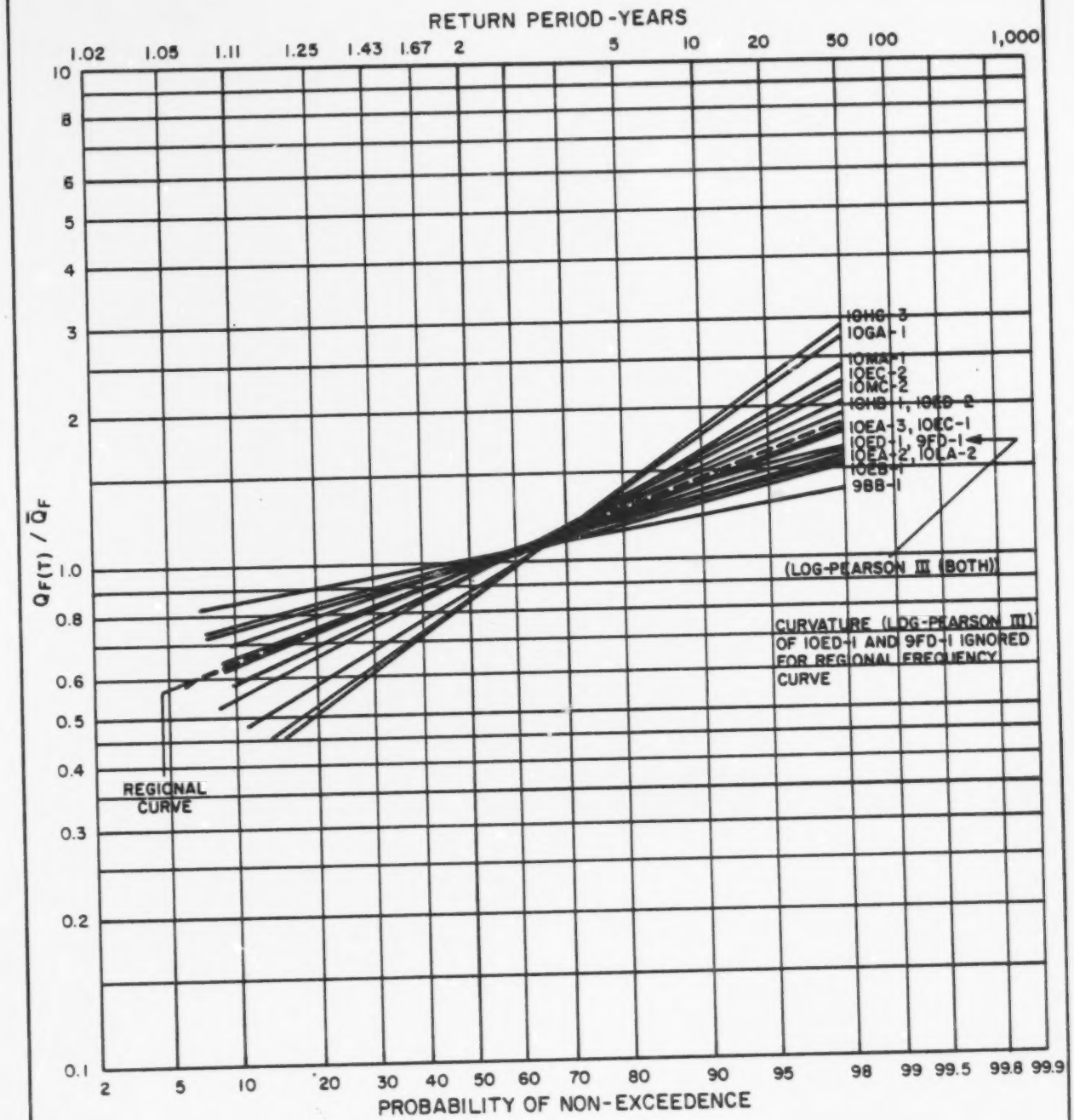
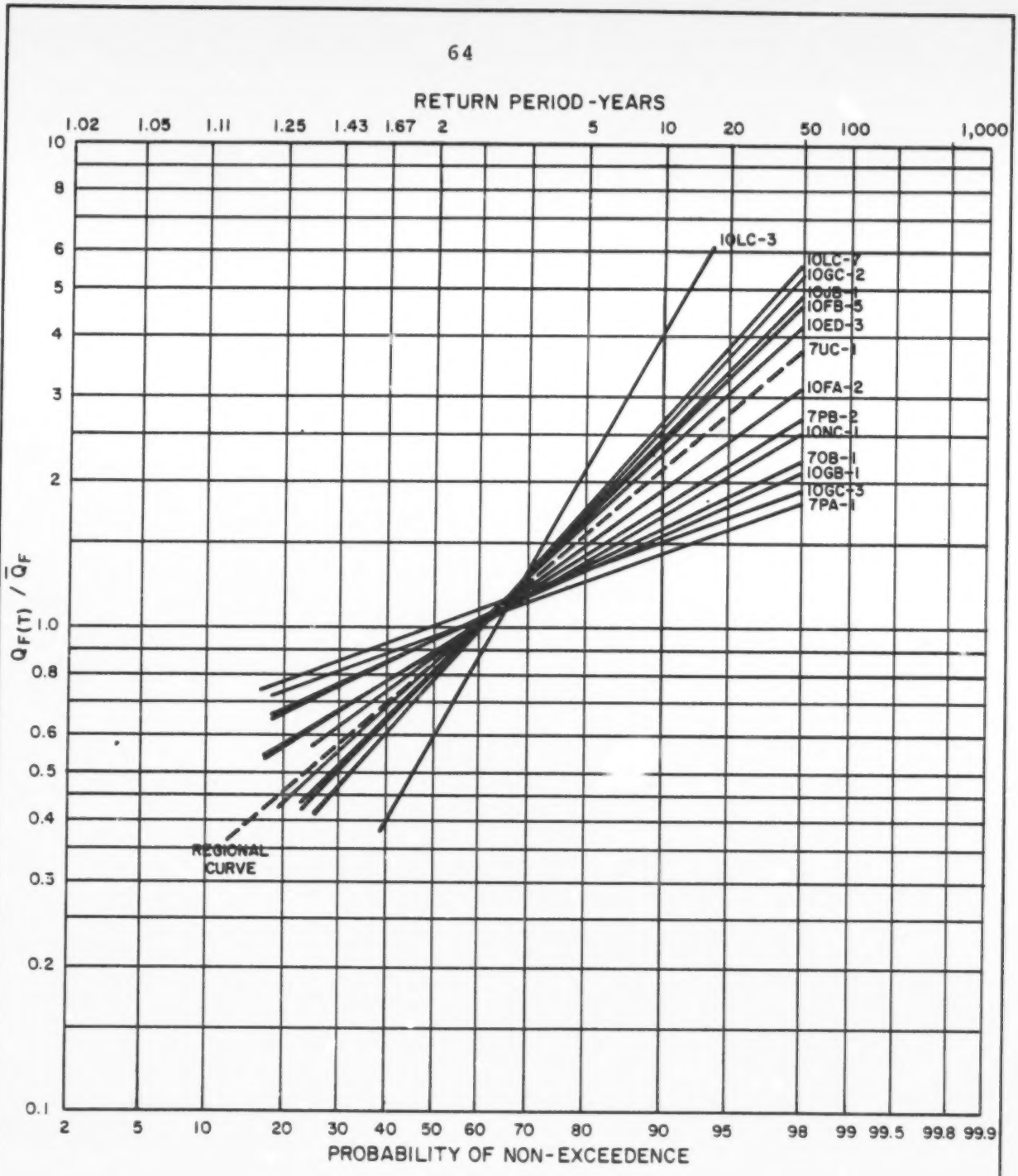


FIG. 6.1

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

NONDIMENSIONAL FLOOD FREQUENCY CURVES-CORDILLERAN REGION



DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

FIG. 6.2

NON-DIMENSIONAL FLOOD FREQUENCY CURVES - INTERIOR PLAINS REGION

ACRES

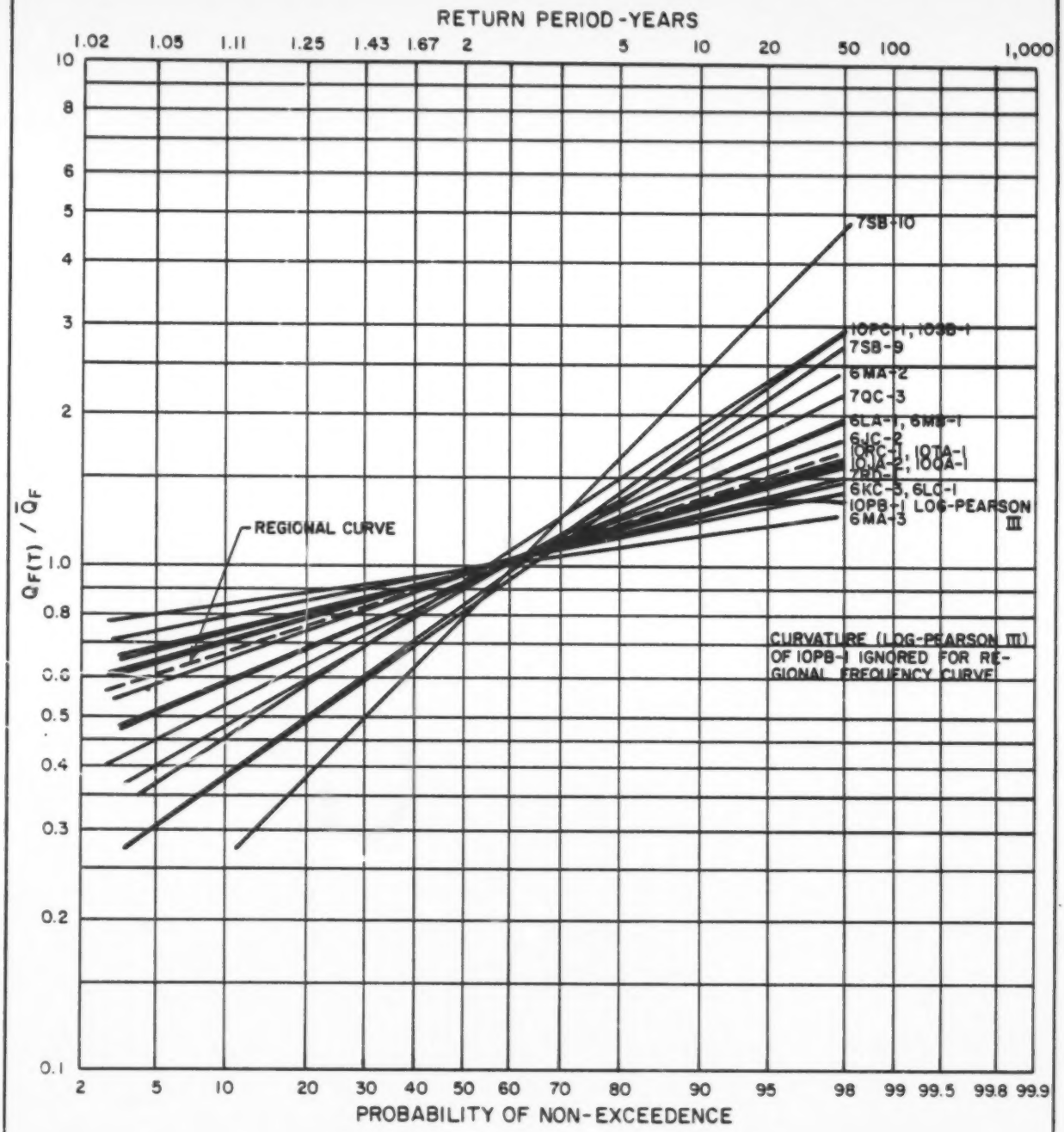


FIG. 6.3

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

NON-DIMENSIONAL FLOOD FREQUENCY CURVES - CANADIAN SHIELD REGION

ACRES

physiographic regions. The median frequency curves for each of these regions are also shown. The Shield Region curve, influenced by large amounts of lake storage, has the shallowest slope, indicating a smaller variance in annual flood from the mean flood.

Langbein's homogeneity test for flood frequency data was conducted for each physiographic region. The results presented in Figure 6.4 show the following factors.

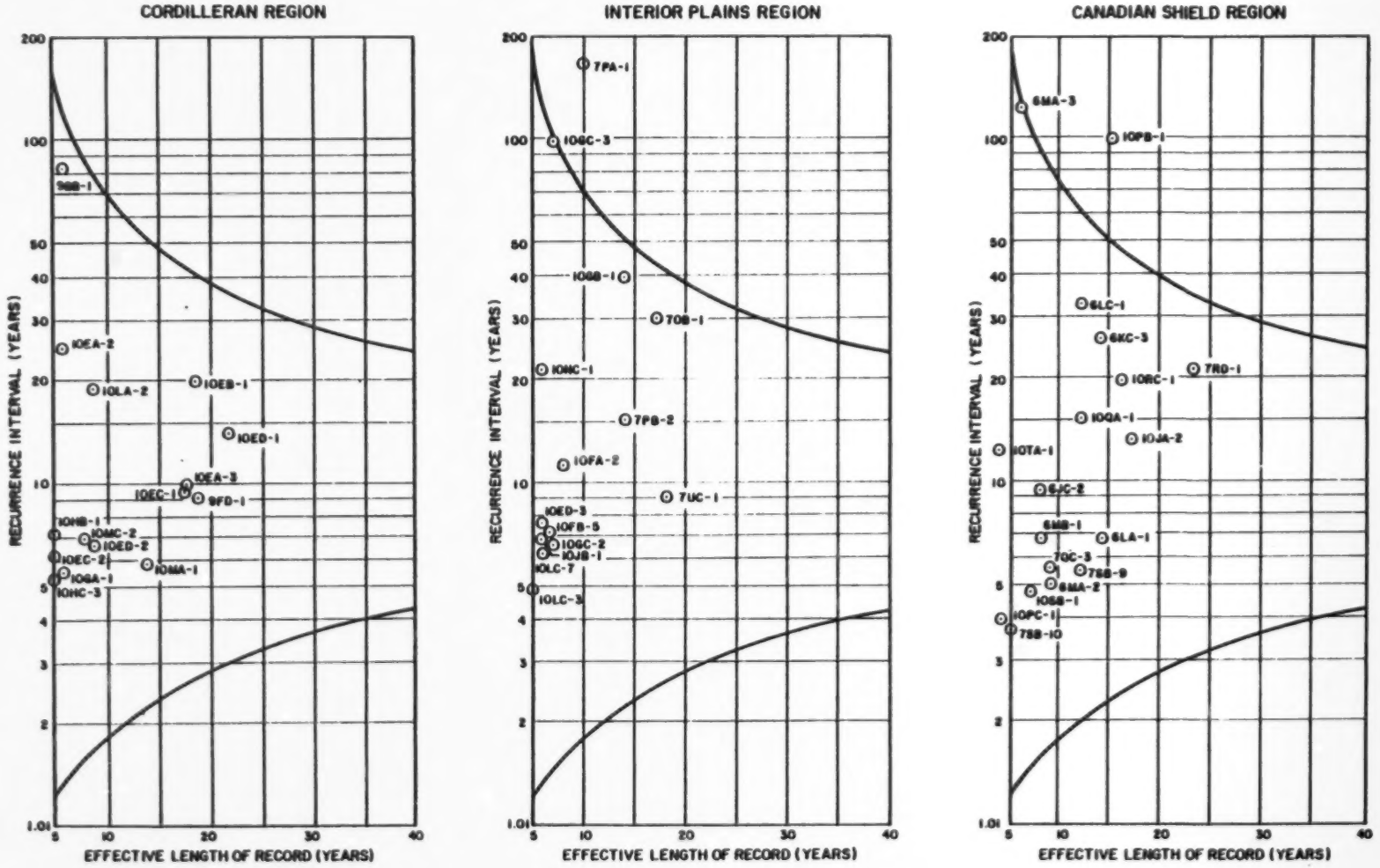
- All 15 Cordilleran Region basins are homogeneous although the South MacMillan River (9BB-1) in the Yukon could possibly be an outlier in future studies.

- The Interior Plains Region has two nonhomogeneous basins.

  The Great Bear River (10JC-3) was not included in Figure 6.4 since the large amount of storage in Great Bear Lake causes significant flood attenuation. This factor was well documented in the 1976 study.

  The Buffalo River (7PA-1) was also found to be non-homogeneous as it was for low flows. The reasons are thought to be as follows.

  - The origin of the river is in the Caribou Mountains and about 30 percent of the basin is mountainous. This is uncharacteristic of an Interior Plains catchment.



DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

HOMOGENEITY TEST CHART

FIG. 6.4

- Near the gauge, the river flows through a relatively large lake and then through a small flat outlet into Great Slave Lake.

  Flood frequency curves for both the Buffalo River and Great Bear River are produced on Plate 19.

- The Canadian Shield Region has one basin which appears nonhomogeneous--the Coppermine River (10PB-1). No reason for nonhomogeneity can be found and therefore this river is currently included in the homogeneous region because a minor change in skewness could move the station within the test limits.

The median frequency curves of Figures 6.1, 6.2 and 6.3 are reproduced for clarity on Figure 6.5. These frequency curves are recommended for use when extending data to ungauged locations.

In applying the nondimensional frequency curves to an ungauged location, an estimate must be made of the mean annual flood peak. A general equation relating the mean annual flood to physiographic and climatic parameters was developed using the independent variables listed in Sections 5.2.1 and 5.2.2. A multiple linear regression computer analysis was performed using a backward elimination procedure and the F-statistic at a 90 percent confidence level as the criterion for selection or rejection of each variable.

After investigating a large number of combinations of parameters, the following relationships were selected as being the most appropriate.

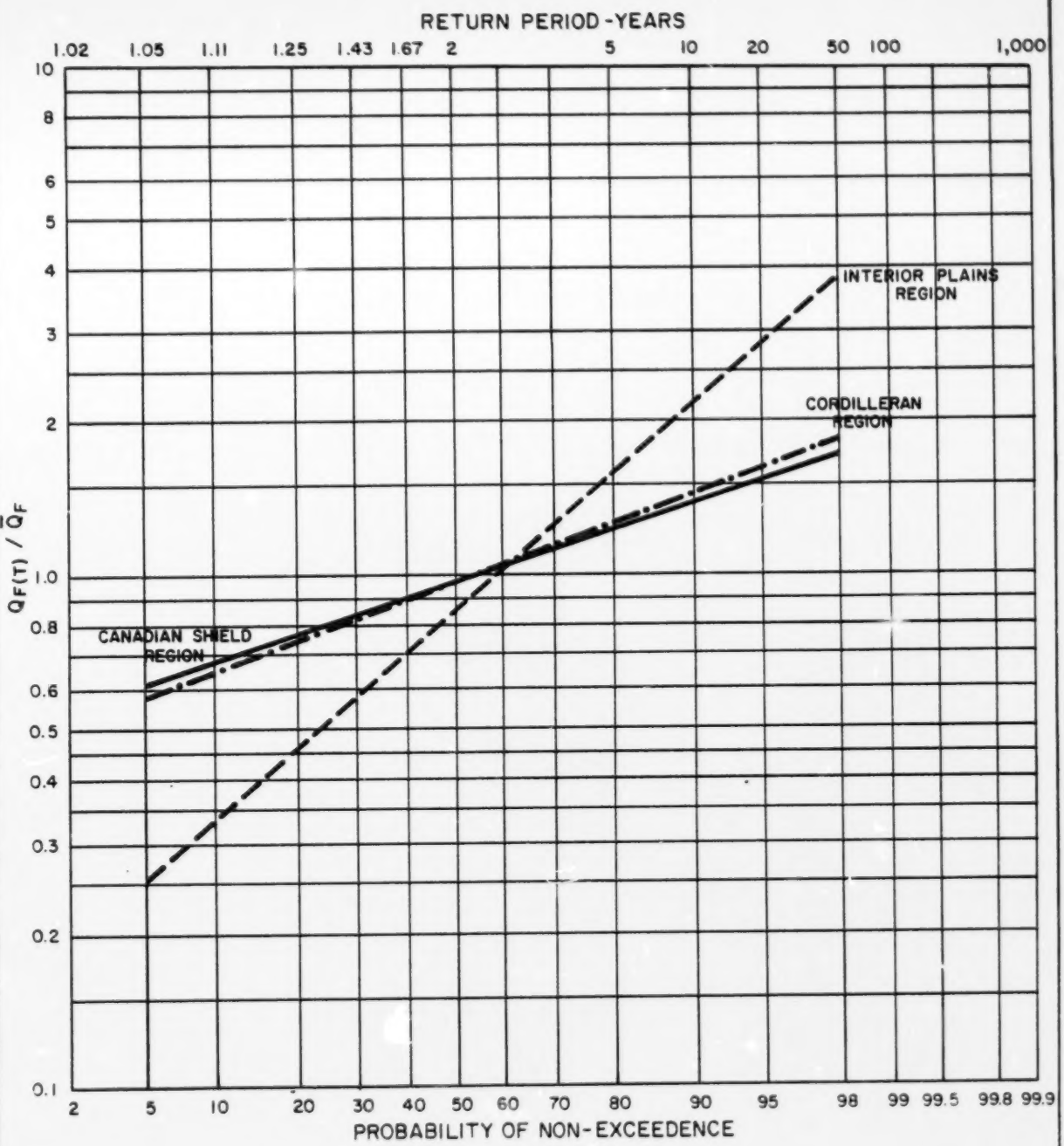


FIG. 6.5

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

NONDIMENSIONAL REGIONAL FLOOD FREQUENCY CURVES

ACRES

Cordilleran Region

$$\overline{Q}_F = 0.224\ A^{0.894} \quad \ldots\ (6\text{-}1)$$

where $\overline{Q}F$ is the mean annual flood peak in cubic metres per second and A is the basin area in square kilometres.

The coefficient of determination of the regression equation is 0.988 and 15 basins were included in the analysis.

Interior Plains Region

$$\overline{Q}_F = 3.526\ A^{0.924}\ S^{0.488}\ (T_{MA}+13)^{-0.547} \quad \ldots\ (6\text{-}2)$$

where S is the dimensional slope and T_{MA} is the annual mean daily temperature in degrees Celsuis.

The coefficient of determination of the regression equation is 0.873 and 13 basins were included in the analysis.

Canadian Shield Region

$$\overline{Q}_F = 0.0235\ A^{0.977}\ (T_{MA}+16)^{-1.257}\ A_{TOT}^{-1.266} \ldots (6\text{-}3)$$

where A_{TOT} is the proportion of lake area in the basin.

The coefficient of determination of the regression equation is 0.902 and 18 basins were included in the analysis.

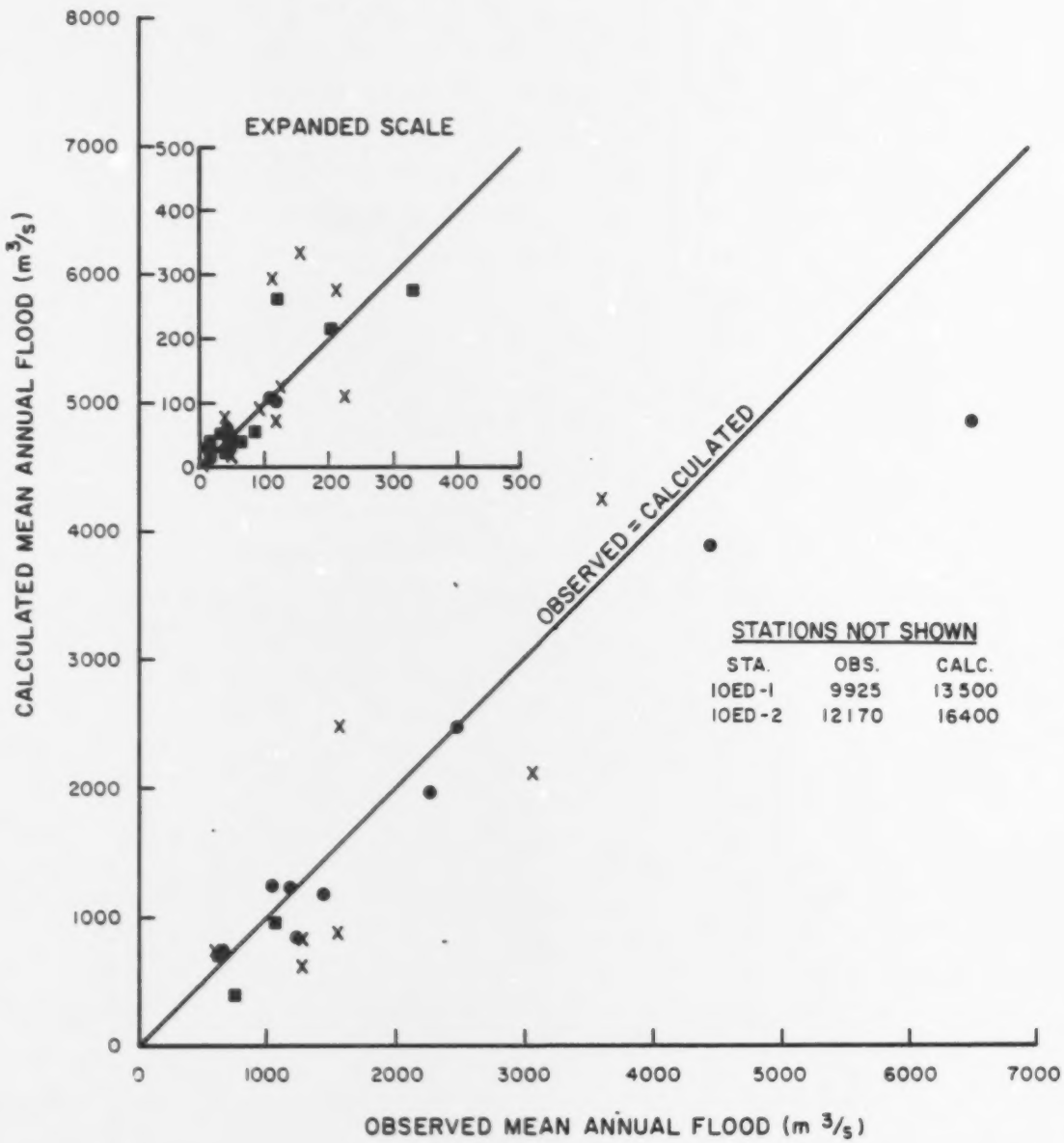
Figure 6.6 is a plot of observed mean annual floods at gauged locations versus computed values from the above equations. This figure shows the magnitude of the error which might be expected from the use of these equations.

It should be noted that predictions for other return periods will be progressively poorer as the return period increases. At higher return periods the predicted flood could be in error not only because of poor predictions of the mean annual flood but also because the regional frequency curve slope will not accurately represent all basins.

The form of these equations is consistent with physiographic and climatic parameters which can be expected to influence peak flow. In the mountains, (Cordilleran Region), the unit peak discharge (discharge per unit area) decreases with increasing basin size. This is logical since the larger basins have an attenuating effect on the flood and do not produce flood events of the same intensity per unit area.

The peak discharge in the Plains Region is shown to be directly proportional to drainage area and slope, and inversely proportional to mean annual temperature. The peak discharge in the Canadian Shield Region is shown to be directly proportional to drainage area and inversely proportional to mean annual temperature and proportion of lake area.

Flood peaks will naturally increase with increasing drainage area. Slope, in conjunction with drainage area, is an indicator of basin concentration time. As the slope increases, the time required for the whole



STATIONS NOT SHOWN

STA.	OBS.	CALC.
10ED-1	9925	13500
10ED-2	12170	16400

LEGEND

- ● CORDILLERAN REGION
- ■ INTERIOR PLAINS REGION
- X CANADIAN SHIELD REGION

FIG. 6.6

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

MEAN ANNUAL FLOOD - COMPARISON OF OBSERVED AND CALCULATED VALUES

ACRES

basin to contribute to the discharge at the outlet decreases and the peak of the flood hydrograph therefore increases. Basins with higher slopes have greater mean annual peaks since they are affected by shorter more intense runoff events. Lake area is an indicator of the amount of surface storage. Greater surface storage has an inverse effect on peak flows through attenuation of peaks. Basin slope and lake area are therefore inversely related and should not appear in the same regression equation.

Annual mean daily temperature is a general indicator of a number of phenomena related to temperature.

- Losses due to evapotranspiration increase with increasing temperature, particularly south of the tree line. This has the effect of reducing spring peak discharge.

- The intensity of spring melt generally decreases with increasing annual mean daily temperature, particularly south of the tree line where the snow cover is shaded from insolation.

- The annual mean daily temperature is an indicator of the extent of permafrost. In regions of continuous permafrost (and lower mean annual temperature) a larger proportion of the discharge results from surface runoff which is more direct and therefore more intense than subsurface runoff.

6.2.2 - Direct Regression Equations

As for low flows, significant relationships between flood flows of a given return period and physiographic

and climatic parameters were sought. Examples of this method are the correlations for mean annual floods described in Section 6.2.1. Further relationships for floods with return periods of 5, 10 and 20 years were generated and are presented in Table 6-2. These relationships all have the same form as the relationships for mean annual floods presented in Section 6.2.1. The same arguments concerning the suitability of the previously chosen climatic and physiographic parameters apply in this case.

All of the regression equations produced are significant at a 90 percent confidence level and the results obtained were found to be only marginally poorer than the results obtained using the Index Flood Method. The relationships derived should be reviewed as more data become available.

6.2.3 - Frequency Curve Slope Prediction

This approach is an extension of the Index Flood Method. Instead of assuming that the slope of the regional frequency curve is constant, the slope prediction method assumes that deviations from the regional curve are systematic and due to physiographic and/or climatic forces. The basic equation is

$$\ln Q_{F(T)} = \overline{\ln Q_F} + {}^{*}\ln Q_F{}^{k} \qquad \ldots\ (6\text{-}4)$$

where

$Q_{F(T)}$ is the flood peak with return period T

TABLE 6-2

FLOOD FLOW REGRESSION EQUATION SUMMARY

Cordilleran Region

Return Period	Regression Equation	R^2	Equation Number
Mean Annual	$\bar{Q}_F = 0.224\ A^{0.894}$	0.988	6 -1 (a)
5 year	$Q_{F(5)} = 0.287\ A^{0.894}$	0.985	6 -1 (b)
10 year	$Q_{F(10)} = 0.333\ A^{0.892}$	0.979	6 -1 (c)
20 year	$Q_{F(20)} = 0.390\ A^{0.891}$	0.974	6 -1 (d)

Range of Input Data: $152\ km^2 < A < 277\ 000\ km^2$

Interior Plains Region

Return Period	Regression Equation	R^2	Equation Number
Mean Annual	$\bar{Q}_F = 3.526\ A^{0.924}\ S^{0.488}\ (T_{MA}+13)^{-0.547}$	0.873	6 - 2(a)
5 year	$Q_{F(5)} = 10.00\ A^{0.856}\ S^{0.450}\ (T_{MA}+13)^{-0.686}$	0.849	6 - 2(b)
10 year	$Q_{F(10)} = 22.93\ A^{0.800}\ S^{0.411}\ (T_{MA}+13)^{-0.836}$	0.819	6 - 2(c)
20 year	$Q_{F(20)} = 45.68\ A^{0.750}\ S^{0.372}\ (T_{MA}+13)^{-0.968}$	0.784	6 - 2(d)

Range of Input Data: $500\ km^2 < A < 48\ 400\ km^2$; $0.000304 < S < 0.00555$; $-29.0^{\circ}C < T_{MA} < -20^{\circ}C$

Table 6-2
Flood Flow Regression Equation Summary - 2

Canadian Shield Region

Return Period	Regression Equation	R^2	Equation Number
Mean Annual	$\overline{Q}_F = 0.0235\ A^{0.977}\ A_{TOT}^{-1.266}\ (T_{MA}+16)^{-1.257}$	0.902	6 - 3 (a)
5 year	$Q_{F(5)} = 0.0287\ A^{0.953}\ A_{TOT}^{-1.400}\ (T_{MA}+16)^{-1.219}$	0.903	6 - 3 (b)
10 year	$Q_{F(10)} = 0.0334\ A^{0.930}\ A_{TOT}^{-1.505}\ (T_{MA}+16)^{-1.177}$	0.903	6 - 3 (c)
20 year	$Q_{F(20)} = 0.0387\ A^{0.910}\ A_{TOT}^{-1.588}\ (T_{MA}+16)^{-1.148}$	0.901	6 - 3 (d)

Range of Input Data: $144\ km^2 < A < 154\ 000\ km^2$; $0.096 < A_{TOT} < 0.337$; $-14.5^oC < T_{MA} < -4.5^oC$

LEGEND

$\overline{Q}_F$	mean annual flood (m^3/s)
$Q_{F(5)}$, $Q_{F(10)}$, $Q_{F(20)}$	annual flood with return period of 5, 10 and 20 years
A	drainage area (km^2)
A_{TOT}	proportion of drainage area covered with lakes
S	basin slope
T_{MA}	annual mean daily temperature (^oC)
R^2	coefficient of determination of regression equation.

$\overline{\ln Q_F}$ is the mean of the natural logarithms of annual floods

$^*\ln Q_F$ is the standard deviation of the natural logarithms of annual floods

k is a standardized normal variate.

The mean of the natural logarithms of annual floods in this equation is predicted in a similar manner to the prediction of Equations 6-1, 6-2 and 6-3 for mean annual floods. Similarly a prediction technique for the standard deviation of the natural logarithm of annual floods was sought.

Significant correlations for $\overline{\ln Q_F}$ were found for each region, however, significant relationships could not be found for $^*\ln Q_F$. Therefore, it can be concluded that $^*\ln Q_F$ is not related to physiographic and climatic characteristics (at least within the large region currently used). Without a satisfactory prediction technique for $^*\ln Q_F$, the slope prediction technique reverts to the Index Flood Methods where $^*\ln Q_F$ is taken as the regional median value.

6.2.4 - Summary

The regionalization of flood flow data from the gauged basins gave satisfactory results for both the Index Flood Method and the Direct Regression Equations approach. The Frequency Curve Slope prediction technique was not found to be acceptable. The recommended technique is the Index Flood Method. The regional

frequency curves that were developed for this method are given in Figure 6.5. The predictive equations for the mean annual flood are given in Equations 6-1, 6-2 and 6-3.

These relationships are developed on a better data base than was previously available, however, the data are still relatively sparse considering the average record length and the total area of the mainland Northwest Territories. A larger data base may allow for possible subdivision into smaller hydrologically homogeneous regions. Subsequently, better relationships could be derived, particularly in the Interior Plains Region.

The current relationships are suitable for preliminary feasibility purposes, but should be confirmed by detailed hydrologic analysis for engineering purposes.

6.3 - Application to Ungauged Basins

To use the generalized flood frequency relationship to estimate frequency curves for an ungauged drainage basin, the following steps should be carried out.

(a) Determine if the basin lies within the Cordillera, Plains or Shield physiographic regions. These regions are delineated on Plate 10. Delineate and measure the area of the drainage basin being considered.

(b) Compute the mean annual flood

- If the ungauged basin is in the Cordilleran Region use Equation 6-1 to compute the mean annual flood.

$$\overline{Q}_F = 0.224\ A^{0.894} \quad \ldots\ (6\text{-}1)$$

- If the ungauged basin is in the Interior Plains Region measure the stream slope as described in Section 5.2.1. Plot the centroid of the drainage basin on the map of annual mean daily temperature (Plate 5). Interpolate between isotherms to obtain the annual mean daily temperature. Use Equation 6-2 to compute the mean annual flood.

$$\overline{Q}_F = 3.526\ A^{0.924}\ S^{0.488}\ (T_{MA}+13)^{-0.547} \quad \ldots\ (6\text{-}2)$$

- If the ungauged basin is in the Canadian Shield Region measure the proportion of basin area occupied by lakes as described in Section 5.2.1. Determine the annual mean daily temperature as described for the Interior Plains Region above. Use Equation 6-3 to compute the mean annual flood.

$$\overline{Q}_F = 0.0235\ A^{0.977}\ (T_{MA}+16)^{-1.257}\ A_{TOT}^{-1.266} \ldots\ (6\text{-}3)$$

Since the relationships developed between mean annual flood and physical and climatic factors are obtained from regression analysis, ensure that the physical and climatic characteristics of the ungauged basin are within the range used to develop the relationship (see Table 6-1 for a summary of the ranges). If they are not, care should be taken to ensure that the extrapolation is a reasonable one, and that the confidence of the estimate is reduced accordingly.

(c) Select the appropriate nondimensional frequency curve from Figure 6.5. Values of peak flood flow can be determined by multiplying the nondimensional factor for the desired return period (peak flood/mean annual flood) by the mean annual flood determined in Step (b).

6.4 - Example Calculations

6.4.1 - Arctic Red River Near the Mouth (10LA-2)

Step (a) The basin lies within the Cordilleran Region

Drainage area = 15 100 km^2

Step (b) The mean annual flood is computed from Equation 6-1

$$\overline{Q}_F = 0.224\ (15\ 100)^{0.894}$$
$$= 1{,}220\ m^3/s$$

Step (c) From Figure 6.5 select the Cordilleran nondimensional frequency curve

$$Q_{F(5)} = 1.3\ (1{,}220) = 1{,}590\ m^3/s$$

$$Q_{F(10)} = 1.45\ (1{,}220) = 1{,}770\ m^3/s$$

$$Q_{F(20)} = 1.6\ (1{,}220) = 1{,}950\ m^3/s$$

6.4.2 - Liard River Near the Mouth (10ED-2)

Step (a) The basin lies within the Cordilleran Region

Drainage area = 277 000 km^2

Step (b) The mean annual flood is computed from Equation 6-1

$$\overline{Q}_F = 0.224\ (277\ 000)^{0.894}$$

$$= 16\ 400\ m^3/s$$

Step (c) From Figure 6.5, select the Cordilleran nondimensional frequency curve

$$Q_{F(5)} = 1.3\ (16\ 400) = 21\ 300\ m^3/s$$

$$Q_{F(10)} = 1.45\ (16\ 400) = 23\ 800\ m^3/s$$

$$Q_{F(20)} = 1.6\ (16\ 400) = 26\ 200\ m^3/s$$

6.4.3 - Willowlake River Near the Mouth (10GB-1)

Step (a) The basin lies within the Interior Plains Region

Drainage area = 21 600 km^2

Step (b) Stream Slope = 0.0029

Annual Mean Daily Temperature = -5.5°C

The mean annual flood is computed from Equation 6-2

$$\overline{Q}_F = 3.526(21\ 600)^{0.924}(0.0029)^{0.488}(-5.5+13)^{-0.547}$$
$$= 684\ m^3/s$$

Step (c) From Figure 6.5 select the Interior Plains nondimensional frequency curve

$$Q_{F(5)} = 1.7\ (684) = 1,160\ m^3/s$$

$$Q_{F(10)} = 2.2\ (684) = 1,500\ m^3/s$$

$$Q_{F(20)} = 2.85\ (684) = 1,950\ m^3/s$$

6.4.4 - Taltson River Above Porter Lake Outflow (7QD-4)

Step (a) The basin lies within the Canadian Shield Region

Drainage area = 12 800 km^2

Step (b) Proportion of lake area = 0.204

Annual Mean Daily Temperature = -6.0°C

The mean annual flood is computed from Equation 6-3

$$\overline{Q}_F = 0.0235(12\ 800)^{0.977}(-6.0+16)^{-1.257}(0.204)^{-1.266}$$
$$= 100\ m^3/s$$

Step (c) From Figure 6.5 select the Canadian Shield nondimensional frequency curve

$$Q_{F(5)} = 1.2\ (100) = 120\ m^3/s$$

$$Q_{F(10)} = 1.4\ (100) = 140\ m^3/s$$

$$Q_{F(20)} = 1.5\ (100) = 150\ m^3/s$$

7 - HYDROLOGY DOCUMENTATION FOR SPECIFIC RIVERS

7.1 - Rivers Crossing the Sixtieth Parallel

Three major rivers flow northward across the Sixtieth Parallel into the Northwest Territories--the Liard, the Hay and the Slave. Two smaller rivers, the Buffalo and Little Buffalo, also flow northward into the Territories. There are no significant southward flowing rivers.

7.1.1 - Liard River

The Liard River Basin tributary to the stream gauge at Fort Liard (10ED-1) has a catchment area of 222 000 km^2 with the following approximate distribution of drainage area.

Northwest Territories	- 3 percent
Alberta	- 3 percent
British Columbia	- 65 percent
Yukon	- 29 percent

The stream gauge at Fort Liard has been in operation since 1958. Twenty-one years of complete record (1960 to 1980) are available for hydrologic analysis. Mean annual runoff is approximately 284 mm or 1,995 m^3/s with a variance indicated by the frequency distribution shown on Plate 22. The average monthly distribution of runoff is shown in Table 7-1 and in Figure 7.1.

TABLE 7-1

AVERAGE ANNUAL RUNOFF DISTRIBUTION FOR THE LIARD RIVER AT FORT LIARD (10ED-1)

Month	Runoff (mm)	Percent of Total
January	5	1.8
February	4	1.4
March	4	1.4
April	6	2.1
May	37	13.0
June	75	26.3
July	58	20.4
August	36	12.6
September	27	9.5
October	19	6.8
November	8	2.9
December	5	1.8
TOTAL	284	100.0

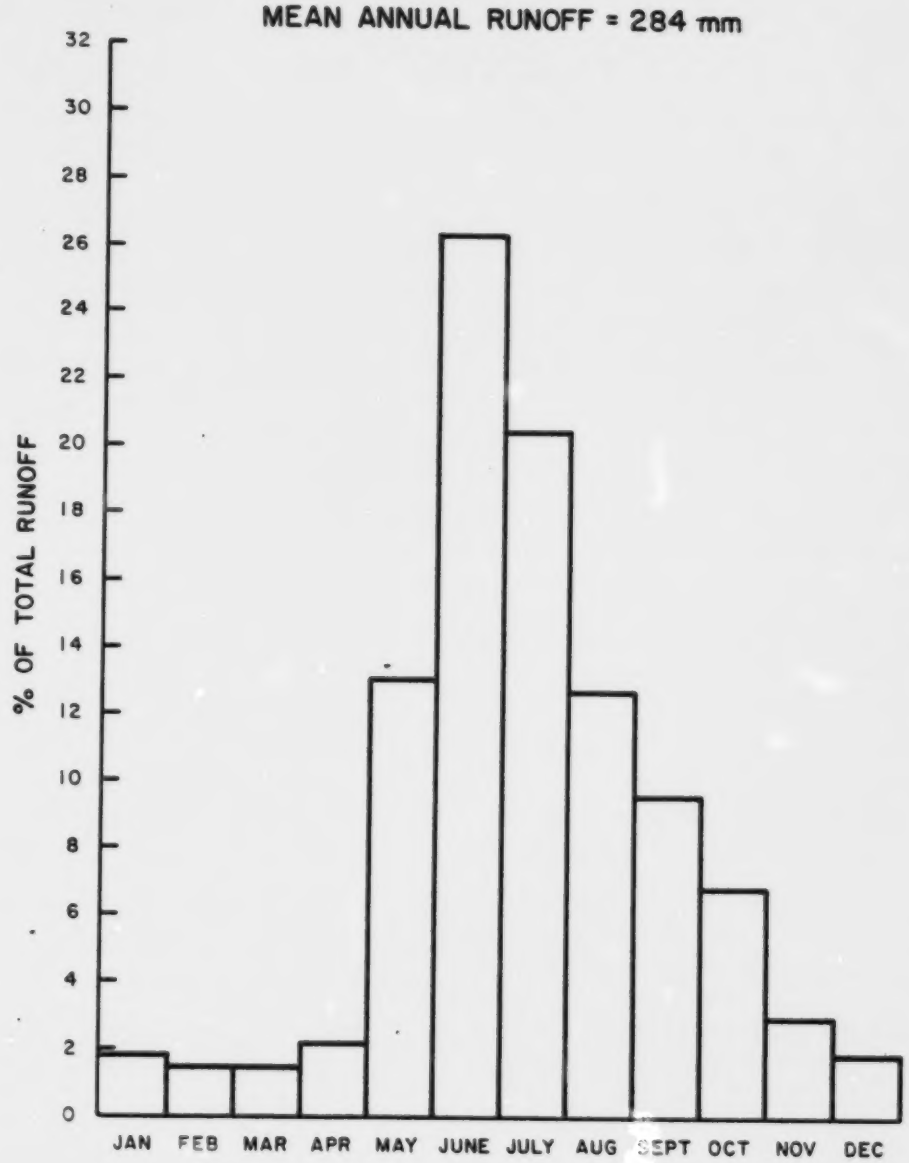


FIG 7.1

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

AVERAGE ANNUAL RUNOFF DISTRIBUTION-LIARD RIVER AT FORT LIARD (10ED-1)

Frequency curves for the mean flows for each month are shown on Plate 22, and a flow duration curve constructed from monthly flows is presented in Figure 7.2.

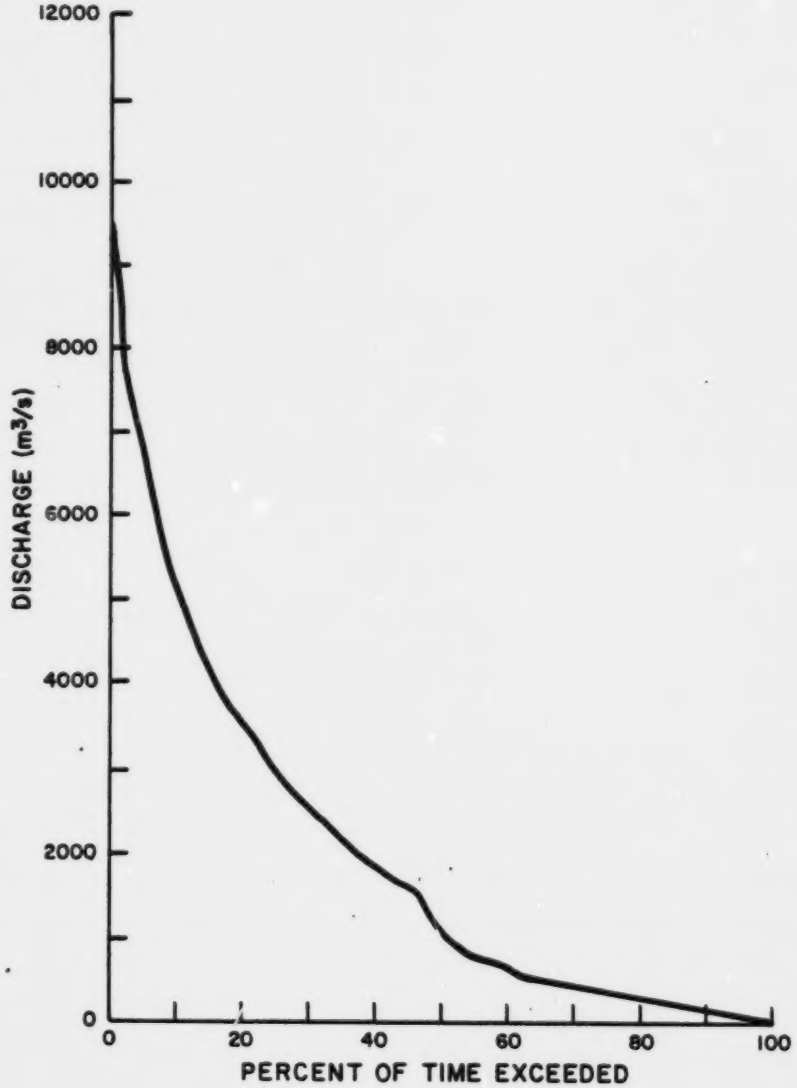
The monthly distribution of runoff shows the runoff regime to be typical of a mountainous basin with a continental climate. Approximately 75 percent of the yearly runoff occurs in the 4 months of May, June, July and August as a result of snowmelt and summer rainfall. Runoff decreases to base flow levels in November, and persists at this level until the following April when snowmelt begins.

The annual peak daily flow normally occurs in mid-June as a result of the spring flood, but has occurred as early as April 30 and as late as July 19. The mean annual flood (peak daily flow) is 9,925 m^3/s. A frequency curve of annual flood flows, fitted using a log-Pearson Type III frequency distribution, is presented on Plate 22.

The 30-day period with the lowest mean flow normally occurs just prior to the commencement of the spring flood. The mean annual value is 292 m^3/s, with a frequency distribution as shown on Plate 22. The mean annual 7-day low value averages only 1.4 percent lower than the 30-day value as might be expected from the hydrologic regime shown in Figure 7.1.

7.1.2 - Hay River

The Hay River Basin tributary to the stream gauge near Hay River (Gauge 70B-1) has a catchment area of 47 900 km^2 with the following approximate distribution of drainage area.



NOTE: BASED ON MONTHLY DATA

FIG. 7.2

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOW DURATION CURVE–LIARD RIVER AT FORT LIARD (10ED-1)

Northwest Territories - 7 percent
Alberta - 75 percent
British Columbia - 18 percent

The stream gauge at Hay River was in operation for some months of years 1929, 1930, 1931 and 1963; however, complete yearly records are available only from 1964. Seventeen years are therefore available for hydrologic analysis.

The mean annual runoff from the basin is 70 mm or 106 m^3/s, with a variance indicated by the frequency distribution shown on Plate 23. The monthly distribution of runoff is shown in Table 7-2 and in Figure 7.3.

Frequency curves for the mean flows for each month are shown on Plate 23, and a flow duration curve constructed from monthly flows is shown in Figure 7.4.

Most of the drainage area of the Hay River is located in the Interior Plains Region. Relief is flat relative to the Liard Basin, but both on-channel and off-channel storages are low. With limited storage, the discharge of the Hay River typically decreases from a peak in May to base flow levels in November. Base flow discharge persists until April of the following year when snowmelt begins. As in the Liard Basin, a high percentage of yearly runoff (about 78 percent) occurs in the 4 months of May, June, July and August.

Peak daily discharge typically occurs in early May, historical records showing a range from April 29 to June 14. The mean value is 741 m^3/s, with the frequency distribution shown on Plate 23.

TABLE 7-2

AVERAGE ANNUAL RUNOFF DISTRIBUTION FOR THE HAY RIVER NEAR HAY RIVER (70B-1)

Month	Runoff (mm)	Percent of Total
January	0.3	0.4
February	0.1	0.2
March	0.1	0.2
April	3	4.9
May	23	32.4
June	15	21.1
July	10	14.3
August	7	10.1
September	5	7.5
October	4	5.5
November	1.9	2.5
December	0.6	0.9
TOTAL	70.0	100.0

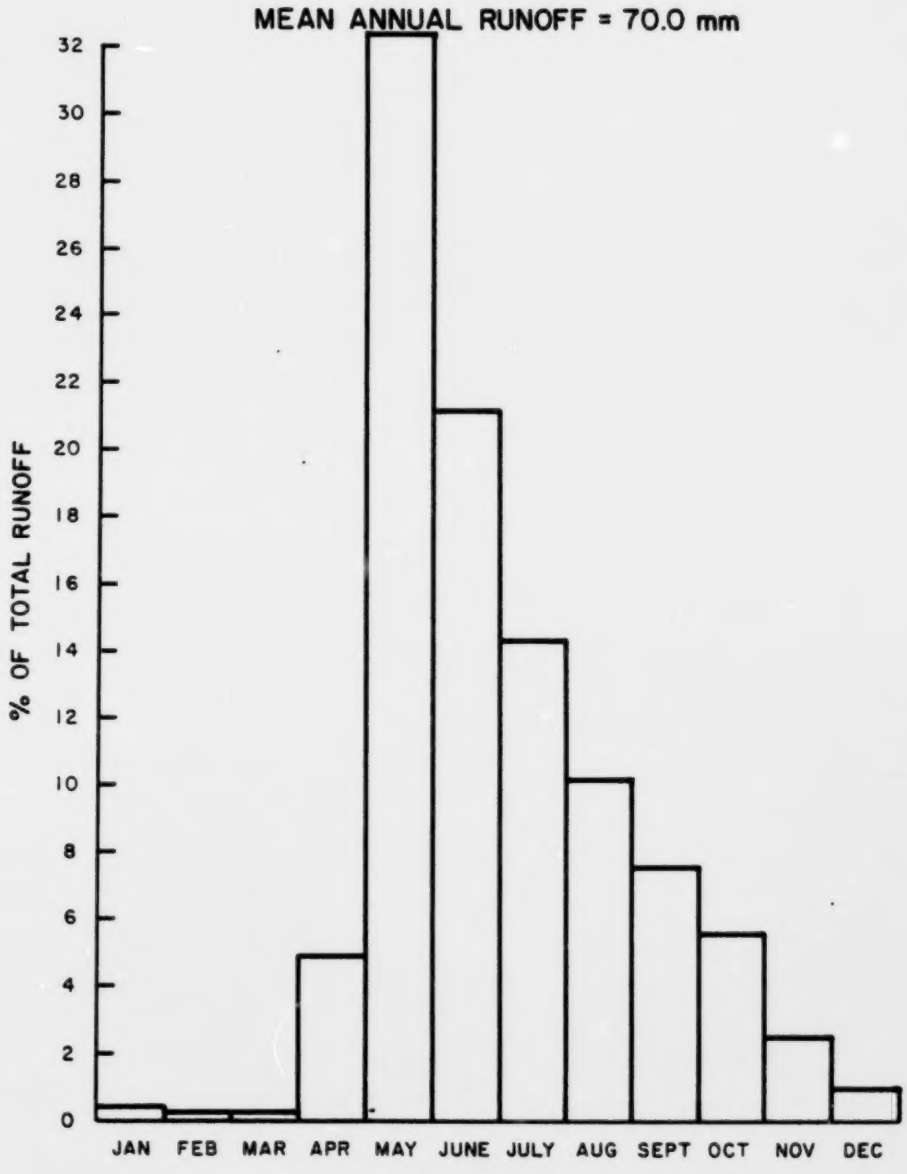
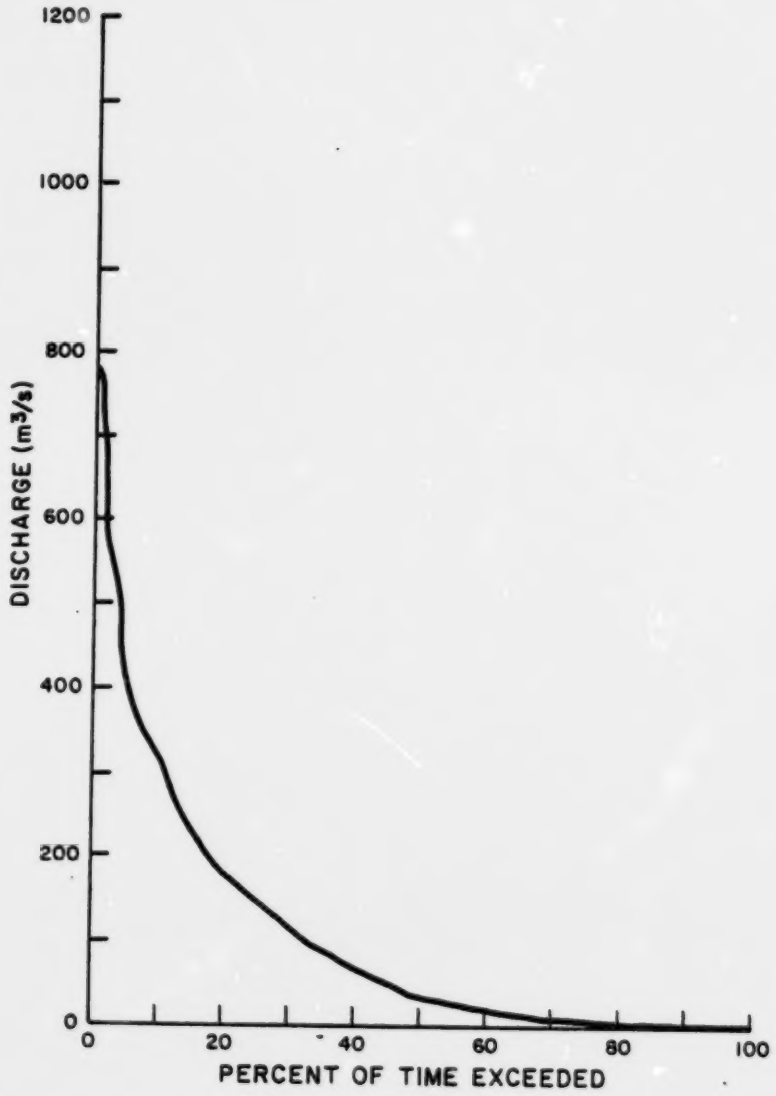


FIG. 7.3

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

AVERAGE ANNUAL RUNOFF DISTRIBUTION – HAY RIVER NEAR HAY RIVER (70B-1)



NOTE: BASED ON MONTHLY DATA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

FIG 7.4

FLOW DURATION CURVE - HAY RIVER NEAR HAY RIVER (70B-1)

ACRES

The mean annual 30-day low flow is 2.12 m^3/s, with the frequency distribution shown on Plate 23. The 30-day low flow period typically occurs just prior to spring breakup.

7.1.3 - Buffalo River

The Buffalo River tributary to the stream gauge at Highway 5 (7PA-1) has a catchment area of 17 800 km^2. The following is the approximate distribution of drainage area.

Northwest Territories - 40 percent
Alberta - 60 percent

The stream gauge has been in operation since October 1968. However, 3 months of data are missing from both 1969 and 1971. Ten years of record were used for flood analysis--1969 to 1979, excluding 1971. Flow data during the flood months are missing from the records for 1980.

The mean annual runoff from the basin is 83 mm, which converts to 47 m^3/s. Annual variance is indicated by the frequency distribution shown on Plate 24. The monthly distribution of runoff is shown in Table 7-3 and in Figure 7.5.

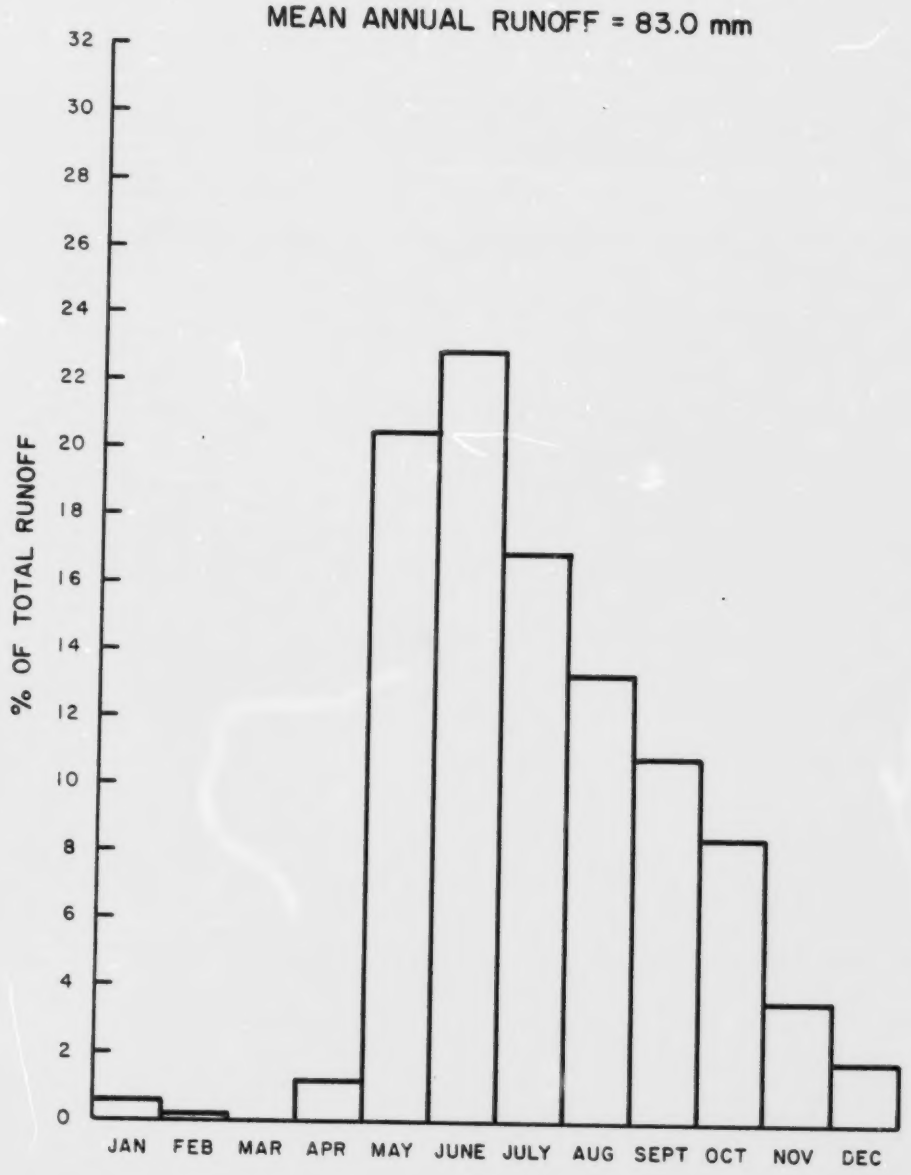
Frequency curves for the mean flows for each month are shown on Plate 24, and a flow duration curve constructed from monthly flows is shown in Figure 7.6.

The Buffalo River is located in the Interior Plains physiographic region, with headwaters in the Caribou Mountains. Although some on-channel storage is

TABLE 7-3

AVERAGE ANNUAL RUNOFF DISTRIBUTION FOR THE BUFFALO RIVER AT HIGHWAY 5 (7PA-1)

Month	Runoff (mm)	Percent of Total
January	0.4	0.5
February	0.1	0.1
March	0.0	0.0
April	1.0	1.2
May	17	20.5
June	19	22.9
July	14	16.9
August	11	13.3
September	9	10.8
October	7	8.4
November	3	3.6
December	1.5	1.8
TOTAL	83.0	100.0



DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

AVERAGE ANNUAL RUNOFF DISTRIBUTION - BUFFALO RIVER AT HIGHWAY 5 (7PA-1)

FIG. 7.5

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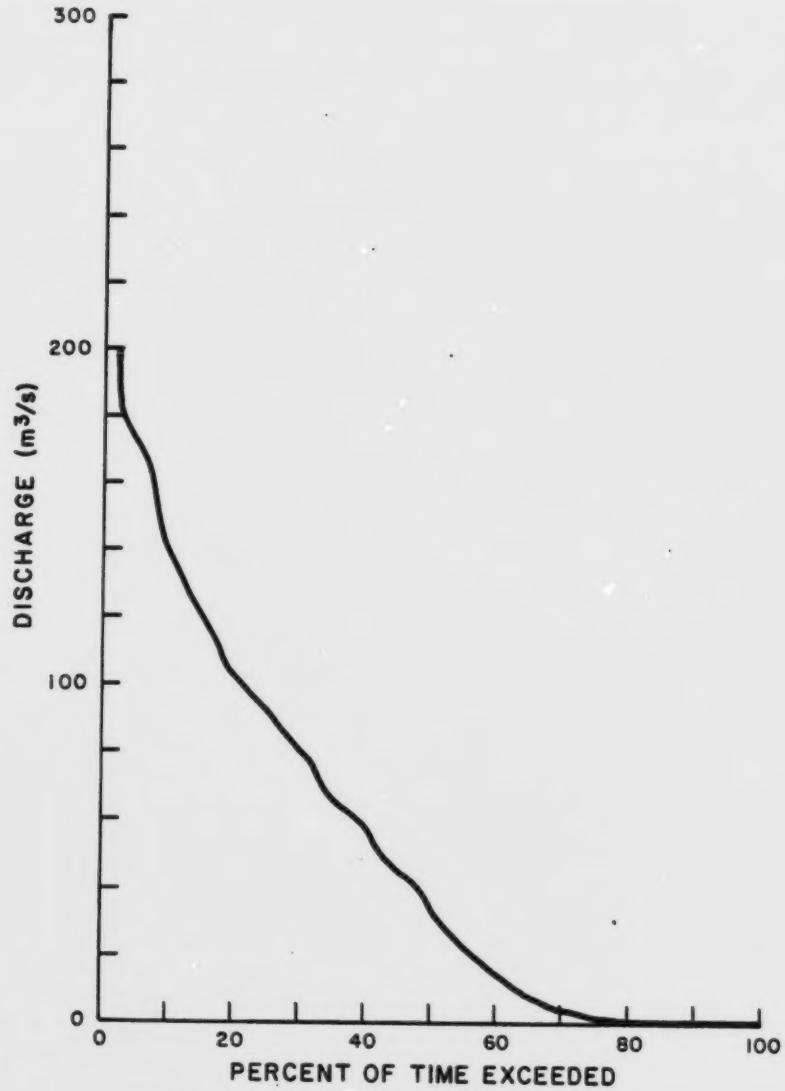

NOTE: BASED ON MONTHLY DATA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

FIG. 7.6

FLOW DURATION CURVE – BUFFALO RIVER AT HIGHWAY 5 (7PA-1)

AGRES

provided by Buffalo Lake, discharge drops to low levels by November. In most years, the discharge drops to zero in March. This probably results from a depletion of storage to low levels and solid freezing of the channel.

The Buffalo River was excluded from regional analysis because it was found to be nonhomogeneous with the rest of the Interior Plains Region. The reasons for non-homogeneity are thought to be as follows.

- The river originates in the Caribou Mountains, a characteristic which is not representative of the Interior Plains basins.

- The river near the gauge flows through a relatively large lake and then through a small flat outlet into Great Slave Lake.

The annual flood can occur as a result of snowmelt or heavy summer rain. This behavior is indicative of the relatively small drainage basin area. Peak daily discharge for half the period of record was caused by snowmelt, and for half by heavy rain. The mean annual flood (combined snowmelt plus rain) is 197 m^3/s with variance indicated by the frequency distribution plotted on Plate 24.

The 30-day low flow of the Buffalo River was measured as zero in 8 of the 12 years of record. In the other 4 years, the 30-day low flow was always less than 0.15 m^3/s. The frequency distribution of 30-day low flow is shown on Plate 24.

7.1.4 - Little Buffalo River

The catchment area of the Little Buffalo River to the stream gauge near Pine Point Highway (7PB-2) is 3,600 km^2. Virtually all of the drainage basin lies within Alberta.

The gauge has been operating since 1965, but complete data are available for the months of May through October only. One year, 1973, has a complete record.

The mean annual flow of the Little Buffalo could not be extended due to the insufficient period on which to base a correlation. From the available record, however, the mean annual runoff is estimated as 45 mm or 5.1 m^3/s. There are insufficient data to estimate reliably the monthly distribution of runoff.

As with the Buffalo River, the annual flood can result from either snowmelt or a summer rainstorm. In the 14 years of record available during the flood period, snowmelt caused the peak flow 12 times, with peak dates ranging between May 1 and May 16. In 1973 and 1975 the flood peaks were caused by rainstorms in August. The mean annual flood of combined snowmelt and rainfall events is 15 m^3/s with a variance indicated by the frequency distribution on Plate 25.

The Little Buffalo has a similar hydrologic regime to that of the Buffalo. Periods of zero flow are expected to occur frequently in January, February and March.

There are insufficient data on which to base an analysis of 30-day low flows; however, the 1 year of complete record and the size of the basin indicate that the 30-day low flow will be zero in most years.

7.1.5 - Slave River

The drainage area of the Slave River at Fitzgerald, Alberta (7NB-1), is 606 000 km^2. All of this basin lies outside the boundaries of the Northwest Territories.

Continuous records since 1960 are available for this station. Nearly complete records are also available for the months June through October between 1953 and 1959, and for the years 1921 and 1922.

Runoff from 70 000 km^2 of this catchment has been regulated since 1968 by the W.A.C. Bennett dam located on the Peace River in British Columbia. The fill period of the reservoir had a significant effect on the mean annual runoff. Therefore, the 4 years (1968 to 1971) of filling were excluded from the analysis which was performed on both preregulation and postregulation data. The mean annual runoff during the preregulation period (until 1967) was 195 mm (3,740 m^3/s), and during the postregulation period (1972 to 1980) it was 188 mm (3,600 m^3/s). This difference is not of great significance. The variance of both periods is indicated by the frequency plot on Plate 27. The monthly distribution of runoff for both periods is given in Table 7-4 and in Figure 7.7.

Frequency curves for the mean monthly flows for each month in both periods are shown on Plates 26 and 27. Flow duration curves constructed from monthly flows are shown in Figure 7.8.

The Slave River is fed by three major tributary systems: the Peace River, with a drainage area of

TABLE 7-4

AVERAGE ANNUAL RUNOFF
DISTRIBUTION FOR THE SLAVE RIVER
AT FITZGERALD, ALBERTA (7NB-1)

Month	Runoff		Percent of Total	
	Until 1967 (mm)	1972 to 1980 (mm)	Until 1967	1972 to 1980
January	8	10	4.3	5.3
February	7	10	3.7	5.3
March	6	10	3.1	5.2
April	6	10	3.2	5.6
May	20	21	10.3	11.2
June	31	25	15.9	13.1
July	31	24	15.6	12.6
August	26	20	12.9	10.8
September	21	18	10.9	9.7
October	19	17	9.8	9.1
November	12	13	6.1	6.9
December	8	10	4.2	5.2
TOTAL	195	188	100.0	100.0

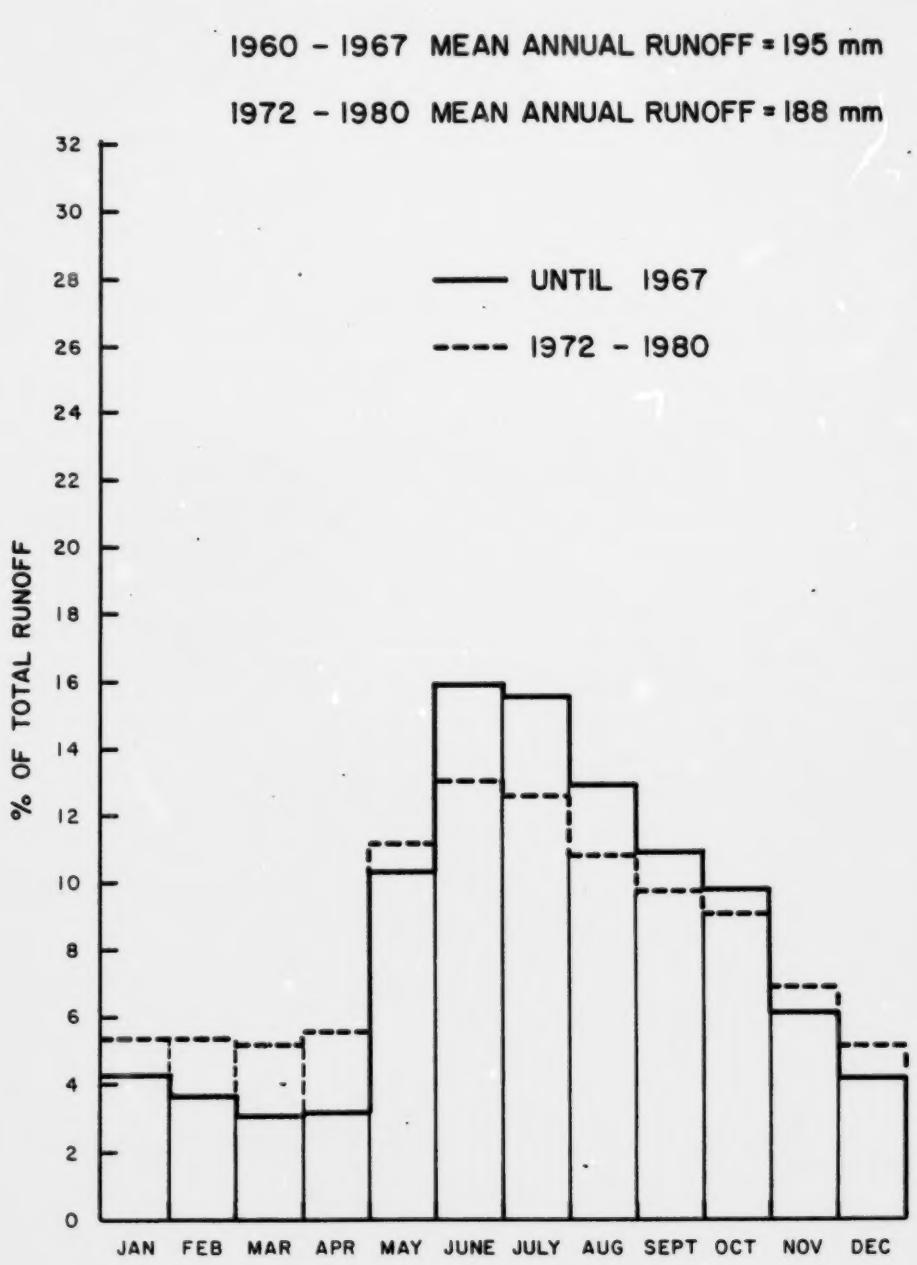

FIG. 7.7

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NORTHWEST TERRITORIES WATER RESOURCE STUDY

AVERAGE ANNUAL RUNOFF DISTRIBUTION - SLAVE RIVER AT FITZGERALD, ALBERTA (7NB-1)

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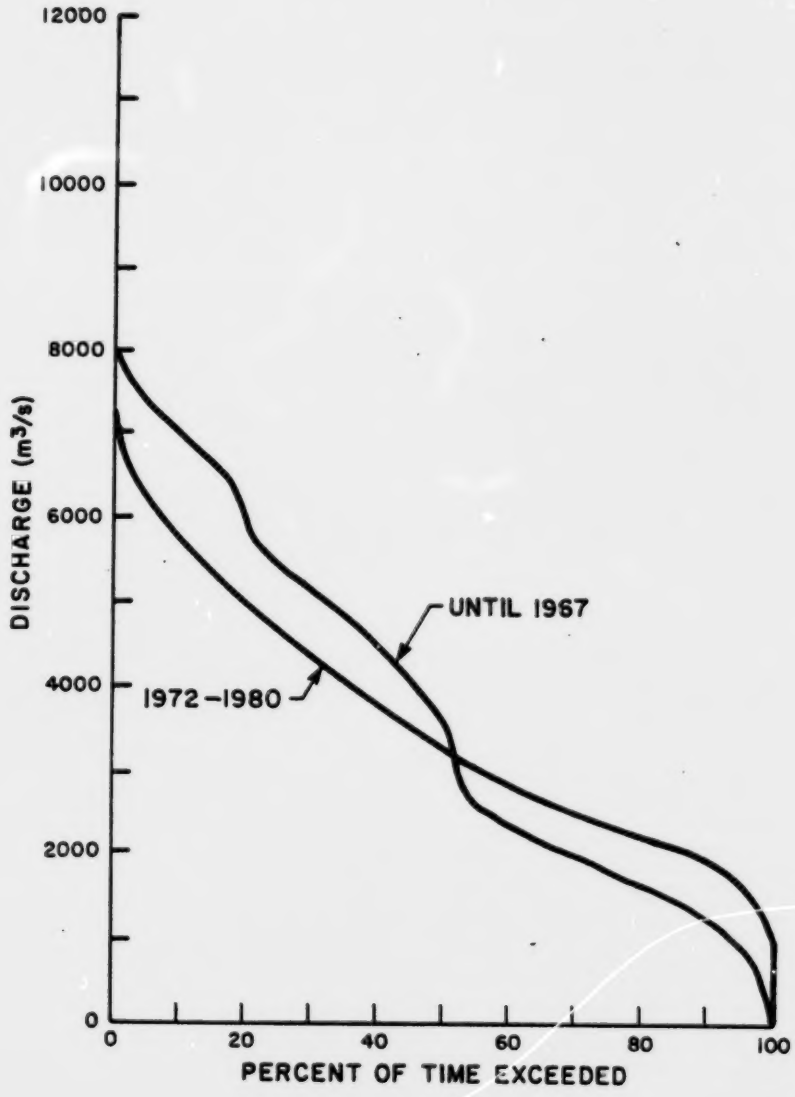


NOTE: BASED ON MONTHLY DATA

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

FIG. 7.8

FLOW DURATION CURVES–SLAVE RIVER AT FITZGERALD, ALBERTA (7NB-1)

AGRES

303 000 km^2; the Athabaska River, with a drainage area of 162 000 km^2; and the Fond du Lac River draining through Lake Athabaska. The system drains portions of the Cordilleran, Interior Plains and Canadian Shield physiographic regions. Runoff is dampened by the effects of off-channel storage in the Shield Region as well as the significant storage of Lake Athabaska. Runoff in the 4-month period from June through September is approximately 50 percent of the yearly total. The runoff was 22 mm higher during the preregulation period than during postregulation. The 4-month summer runoff has therefore decreased 20 percent (from 109 to 89 mm) since regulation occurred.

The peak daily discharge occurs most frequently in June, but has occurred as late as August in both time periods (1957 and 1976). The mean annual flood for the preregulation period is 7,580 m^3/s. The mean annual flood for the postregulation period is 6,920 m^3/s. The frequency distributions are shown on Plate 27.

Analyses of 30-day low flows indicate a mean annual value of 1,150 m^3/s for the preregulation period and 2,070 m^3/s for the postregulation period. The frequency curves of 30-day low flow are given on Plate 27.

7.2 - Mackenzie River

Since the Mackenzie River has great significance to the Northwest Territories, a representative stream gauge (Norman Wells) was chosen for analysis.

The Mackenzie River Basin tributary to the stream gauge at Norman Wells (10KA-1) has a catchment area of 1 570 000 km^2 with approximately 57 percent being outside the Northwest Territories (predominantly Alberta and British Columbia).

The stream gauge at Norman Wells has been in operation since 1943, however, in the early years of record data are available only from June to September. The record is complete since 1966. Runoff from 70 000 km^2 of the Slave River has been regulated since 1968. The effect of this regulation on the flow regime of Norman Wells is not thought to be large, however, it is difficult to assess accurately because the available data prior to 1968 are limited. The 4 years (1968 to 1971) of reservoir filling were excluded from all analysis.

The mean annual runoff from 1972 to 1980 is approximately 177 m (8,790 m^3/s) with a variance indicated by the frequency distribution shown on Plate 28. The average monthly distribution of runoff for the 1972 to 1980 period is shown in Table 7-5 and in Figure 7.9.

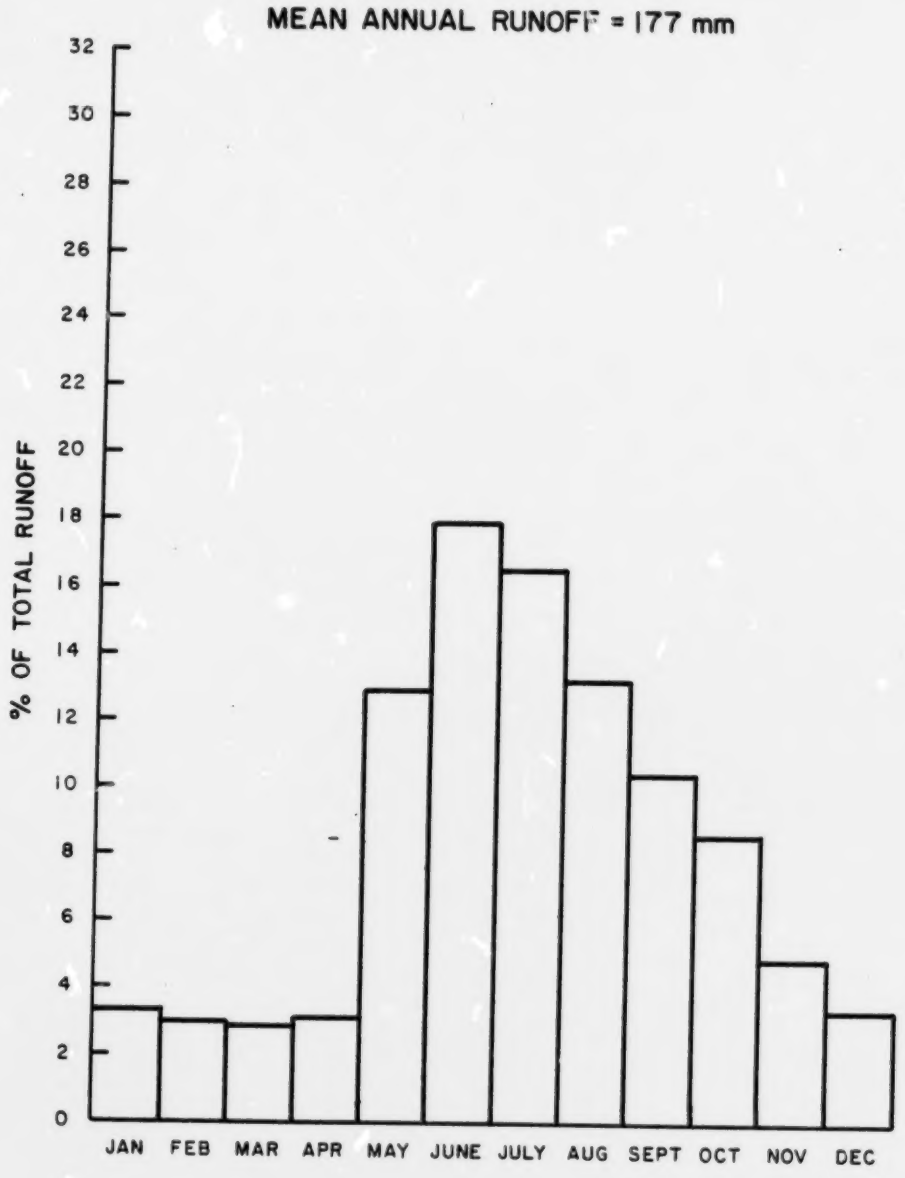
Frequency curves for the mean flows for each month are shown on Plate 28. Monthly frequency curves for the preregulation period during the summer months are also presented. These preregulation and postregulation frequency curves demonstrate that the flow is higher during the postregulation period in June, July and August and is approximately the same during September. The full effect of regulation on the redistribution of the annual flows cannot be assessed because there is insufficient preregulation data for the other 8 months. A flow duration curve constructed from monthly postregulation flows is presented in Figure 7.10.

The Mackenzie River is fed by two major tributary systems: the Liard River, with a drainage area of 277 000 km^2 and

TABLE 7-5

AVERAGE ANNUAL RUNOFF DISTRIBUTION FOR THE MACKENZIE RIVER AT NORMAN WELLS (10KA-1)

Month	Runoff (mm)	Percent of Total
January	6	3.3
February	5	3.0
March	5	2.9
April	6	3.1
May	23	12.9
June	32	17.9
July	29	16.5
August	23	13.2
September	18	10.4
October	15	8.6
November	9	4.9
December	6	3.3
TOTAL	177	100.0



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NORTHWEST TERRITORIES WATER RESOURCE STUDY

AVERAGE ANNUAL RUNOFF DISTRIBUTION - MACKENZIE RIVER AT NORMAN WELLS (10KA-1)

FIG. 7.9

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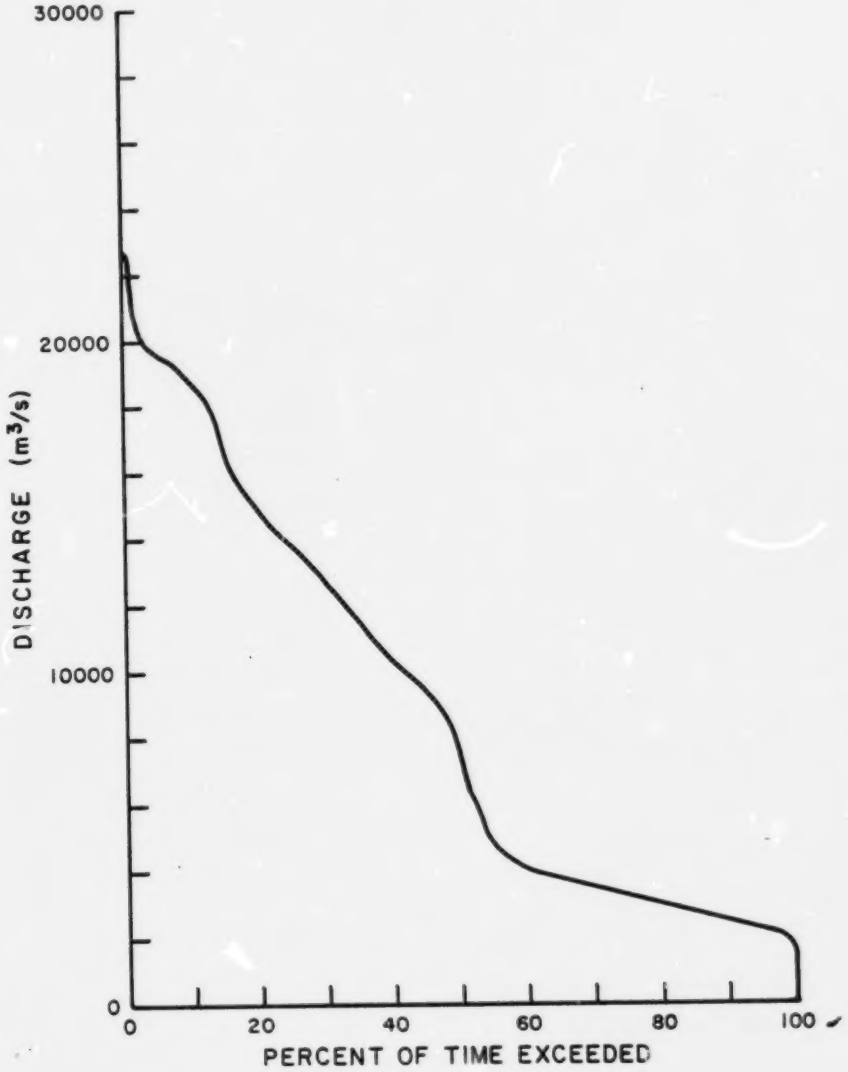

NOTE: BASED ON MONTHLY DATA

FIG. 7.10

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT
NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOW DURATION CURVE–MACKENZIE RIVER AT NORMAN WELLS (10KA-1)

ACRES

the Slave River, with a drainage area of 606 000 km^2. The system drains portions of the Cordilleran, Interior Plains and Canadian Shield physiographic regions. Runoff is dampened by the effects of lake storage, particularly Great Slave Lake and Lake Athabaska.

The peak daily discharge occurs most frequently in June, but can vary from May to July. In 1949, the peak was on August 17. The mean annual flood is 22 200 m^3/s and the frequency distribution is shown on Plate 28. The flood analysis is based on the total period from 1943 to 1980 since the effect of regulation on flood flows should be negligible.

Analysis of 30-day low flows gives a mean annual value of 2,870 m^3/s. The frequency curves of 30-day low flow are given on Plate 28.

8 - FURTHER REQUIREMENTS

Streamflow and meteorological data in the Northwest Territories have been collected over a relatively short period of record from a sparse network of stations. Over the past 5 years, the density of streamflow stations has increased twofold--a significant improvement. In this update study, useful streamflow data are available from approximately twice the number of stations used in the 1976 study. A further update of the current study is recommended 5 years from now when the data base will cover approximately 4 times the number of stations used in the original study. Only the passage of time can lengthen the period of streamflow records at these new stations. To derive maximum benefit from the improved station density, the new gauges must be maintained continuously with as few breaks in the record as possible. The meteorological data base has been marginally improved in the past 5 years, however, the change is minimal in comparison to the streamflow improvements.

This section enumerates those areas for which streamflow and meteorological information is still lacking and suggests some specific studies to provide necessary insight into the hydrologic cycle.

8.1 - Meteorological Network

Climatic stations in the Northwest Territories are concentrated along the Arctic coastline and along the Mackenzie Valley. The stations at lower elevations experience frequent coastal fogs which could significantly alter the apparent climate at inland points. The stations along the Mackenzie Valley do not adequately represent conditions in the nearby

mountain ranges. In the past several years, new climatic stations have been installed both along the Mackenzie Valley and along the Arctic coastline, however, new gauges were not located in the majority of the Interior Plains or in the Canadian Shield. Several new stations were located in the Arctic Islands but all are located in coastal areas. Consequently, the following recommendations are similar to those given in the 1976 study.

- Establishment of a climatic station or stations in the Mackenzie mountains to improve the understanding of the effect of topography on regional weather systems.

- Establishment of more climatic stations on the mainland east of Great Slave Lake and west of Baker Lake. These stations could aid in clarifying the low runoff of the Thelon River watershed. Consideration should be given to installing small automated stations with either telemetering or long-term data storage capabilities.

- Establishment of inland climatic stations on some of the larger Arctic Islands, preferably in conjunction with studies of hydrologic processes in the same area (see Section 8.3).

- Initiation of studies into the accuracy of snowfall measurement, particularly in areas where blowing snow occurs frequently.

8.2 - Stream Gauging Networks

Catchments gauged on the mainland are now well distributed with regard to drainage area. The range of basin areas is as follows.

Cordilleran Region - 152 to 277 000 km^2
median 15 400 km^2

Interior Plains Region - 663 to 146 000 km^2
median 13 100 km^2

Canadian Shield Region - 144 to 154 000 km^2
median 22 000 km^2

The past 5 years have shown a substantial improvement in the areal distribution of stream gauges to the point where many of the data gap areas have been filled. An additional 5 years of record will allow better analysis in

- east Keewatin District (areas draining into Hudson Bay)
- northern Shield area near the Back and Burnside rivers
- area just east of Great Slave Lake in the Taltson and Thelon River basins.

For the most part, it is a matter of time until the records now started have provided sufficient data for analysis. There are, however, some areas which could benefit from a greater density of stream gauges.

- A stream gauge in each of drainage Areas 6JA, 6KA and 6KB would assist in more accurately defining the strong isoline gradients east of Great Slave Lake.
- An additional stream gauge in drainage Area 10RC would collect data in a region which is now sparsely gauged.
- Gauges on the Horton River and/or the Hornaday River or a gauge on the upper reach of the Anderson River in drainage Areas 10NB, 10OA and 10OB would provide data for an area which is also sparsely gauged.

In the Arctic Islands, streamflow data are in particularly short supply. This is a result of the small number of gauges with a sufficiently long record length for analysis and because records are invariably discontinuous.

A number of gauging stations have been installed in the past 5 years and the areal distribution of data in any future updates will be substantially better. It is important that data for these gauges be continuous.

8.3 - Further Studies

Referring to Plate 9, it can be seen that during the past 5 years, 5 gauges have been installed on streams in the Cordilleran Region, 17 in the Plains Region, 25 in the Canadian Shield Region and 5 in the Arctic Islands. Data from these basins will significantly increase the number of basins to be analyzed in each region, possibly allowing the regions to be further subdivided. It is therefore recommended that a further update of this study be conducted 5 years from now. The data base used in this study has been stored on computer tape to facilitate a study update.

When a further update to the study is carried out, some emphasis should be given to the regional analysis of skewness since some long-term records are now showing this tendency.

Recommendations for other studies of the water resources of the Northwest Territories were made in 1976. For the most part, no further research has been undertaken in the areas mentioned and the recommendations stand. For reference, these recommended studies are reiterated here.

Studies of Hydrologic Processes

Research into the hydrologic cycle in the Arctic, particularly in the high Arctic, should be encouraged.

Studies should include in their objectives the determination of the adequacy of existing climatic stations as indicators of regional climate, the validity of conventional snowmelt models, and the means of measuring high Arctic snowfall more accurately. Remote sensing imagery provided by "Landsat" could prove useful in studies of snow accumulation and melting processes. The short duration of the melt period, compared with the longtime interval between satellite passes, however, would limit the usefulness of satellite imagery.

Studies of Regional Factors

As discussed in Sections 3 and 4, vegetation appears to have a strong influence on annual flows on the mainland, especially near the tree line. It is likely that there are also significant differences in hydrologic regime caused by differences in vegetation types north and south of the tree line. It is therefore likely that a 3-level program of vegetation classification into broad categories (using satellite imagery, conventional air photos and ground sampling) would provide necessary information for more detailed regional hydrology studies. The need for this work takes on more importance as the hydrologic data base increases. With more data, more sophisticated analysis will be possible, however, knowledge of the underlying physiographic and climatic characteristics must improve as well.

Groundwater Studies

Although the role of groundwater is small in most basins in the Territories, it appears to be significant south of the continuous permafrost line, particularly in the Mackenzie Mountains. Since low flows are a crucial part of the hydrologic regime for some applications, the contribution of the groundwater storage to low flows deserves more detailed attention.

Groundwater studies could be especially useful in Arctic Island locations, where there have been reports of local areas of year-round groundwater discharge. Such areas could be located using satellite imagery and with the help of local people documented for possible future use.

Physiographic Data

The gathering of physiographic data from topographic maps (1:500 000) forms a significant component of this study. The usefulness of increased streamflow and climatic data may be questionable if parallel steps are not conducted to increase the accuracy of the physiographic data. This is of particular concern with regard to estimating lake areas. It has been noted that the level of lake mapping detail can vary markedly from one map sheet to another--particularly in the northern Interior Plains.

Obtaining improved estimates of physiographic data is a one-time task rather than an ongoing program. It could be conducted using more detailed topographic maps such as 1:250 000 or 1:50 000, where available. The use of satellite data or limited field surveys may also contribute to a better estimate and understanding of the physiographic data.

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TABLE A-1

SUMMARY OF RELATIONSHIPS USED IN EXTENDING ANNUAL RECORDS

Dependent Station	Independent Station	Coefficient* (K)	R^2**	SE*** (percent)
9FD-1	No suitable station			
10MA-1	9FD-1	0.578	0.71	32
10MC-2	10LA-2	0.596	0.82	23
	10MA-1	0.580	0.76	26
	9FD-1	0.451	0.75	30
9BB-1	10HB-1	0.269	0.94	26
	10EC-1	0.761	0.96	27
	10EB-1	0.432	0.93	32
	10EA-3	0.082	0.92	33
10HC-3	10HB-1	0.047	0.88	870[1]
	10JB-1	1.288	0.78	410[1]
10HB-1	10JB-1	0.165	0.91	23
	10GB-1	0.143	0.89	25
	7SB-3	0.184	0.90	26
	10EB-1	0.384	0.88	26
	10JC-3	0.384	0.87	27
10EA-2	10EB-1	0.387	0.91	24
	10EC-1	0.271	0.91	26
	10EA-3	0.256	0.90	26
10EA-3	10EC-1	0.604	0.90	17
	10EB-1	0.374	0.84	23
10EB-1	10EA-3	0.477	0.91	16
	10EC-1	0.374	0.88	18
10EC-1	10EA-3	0.604	0.91	16
	10EB-1	0.477	0.89	17
10EC-2	10EC-1	0.247	0.85	37
	10EB-1	0.131	0.84	45
10GA-1	10GB-1	0.589	0.76	38
	10EC-1	0.265	0.67	49
10LA-2	10MC-2	0.603	0.86	37
10ED-1	10EA-3	0.202	0.84	24

Table A-1
Summary of Relationships Used in
Extending Annual Records - 2

Dependent Station	Independent Station	Coefficient* (K)	R^2**	SE*** (percent)
10ED-2	10ED-1	0.612	0.96	16
	10EC-1	0.623	0.87	21
10LC-3	10LC-7	0.703	0.98	113[1]
10LC-7	10LC-3	0.582	0.74	68[1]
	9FD-1	0.761	0.54	142[1]
10NC-1	No suitable correlation			
10JC-3	10GB-1	0.053	0.40	9
	7SA-3	0.058	0.51	7
10JB-1	10GB-1	0.633	0.82	42
	7SB-3	0.704	0.90	42
10GB-1	No suitable correlation			
10GC-2	No suitable correlation			
10GC-3	No suitable correlation			
10ED-3	No suitable correlation			
10FB-5	10GC-2	0.358	0.54	69
10FA-2	No suitable correlation			
7UC-1	No suitable correlation			
7OB-1	No suitable correlation			
7PB-2	No suitable correlation			
7PA-1	7PB-2	0.480	0.98	36
7QA-1	7UC-1	0.284	0.29	44
7QC-3	7QA-1	0.729	0.76	27
7SB-9	No suitable correlation			
7SB-3	7SA-3	0.833	0.61	44
	10JA-2	1.484	0.52	46
7SA-3	10PB-1	1.251	0.67	24
7RD-1	10PB-1	0.566	0.78	14
	7SB-3	0.160	0.60	16

Table A-1
Summary of Relationships Used in
Extending Annual Records - 3

Dependent Station	Independent Station	Coefficient* (K)	R^2**	SE*** (percent)
10JA-2	7SA-3	0.419	0.60	17
10PB-1	7SA-3	0.415	0.92	15
10PC-1	No suitable correlation			
10QA-1	10PC-1	0.046	0.88	34
	10PB-1	0.511	0.84	38
	10JA-2	0.142	0.81	40
10QD-1	No suitable correlation			
10RC-1	10QD-1	0.078	0.89	40
6JC-2	No suitable correlation			
6MA-3	10RC-1	0.170	0.84	22
	6MB-1	0.083	0.79	23
6JB-1	No suitable correlation			
6KC-3	6JB-1	-0.031	0.73	23
	6LC-1	0.237	0.75	24
	6LA-1	0.386	0.79	26
6LA-1	6LC-1	0.364	0.40	27
	6KC-3	0.668	0.42	32
	6JB-1	0.086	0.44	33
	7RD-1	0.351	0.29	37
6LC-1	6LA-1	0.742	0.98	49
6MA-2	No suitable correlation			
6MB-1	No suitable correlation			
10SB-1	10RC-1	1.721	0.98	46 000[1]
	10QD-1	0.131	0.59	69 000[1]
10TA-1	10QD-1	0.037	0.76	138[1]
	10QA-1	-0.002	0.82	364[1]

* K from regression Equation 4-1
** R^2 - coefficient of determination of the regression
***SE - standard error of regression as a percent
[1] Very large standard error is due to poor estimation of a few very low flows (approaching zero) but relationship adequately represents most data.

TABLE A-2

MONTHLY FLOW DATA - EXTENDED RECORD

Region	WSC Station Number	River Name	Monthly Discharge (m^3/s) Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean Annual (m^3/s)
Cordilleran	9FD-1	Porcupine	22.0	18.7	16.8	16.6	1 050	1 300	508	592	422	136	52.1	31.6	346
	10MA-1	Peel	23.9	19.8	18.6	22.5	528	638	371	336	234	94.6	46.8	31.9	197
	10MC-2	Peel	83.0	73.7	67.7	70.3	2 220	2 810	1 330	1 320	842	354	151	106	792
	9BB-1	South MacMillan	1.99	1.53	1.30	1.46	27.1	85.8	52.4	31.4	19.8	15.3	6.11	2.88	21.0
	10HC-3	Big Smith Creek	0.267	0.159	0.099	0.281	32.6	9.09	3.68	5.12	2.91	3.07	1.33	0.576	5.53
	10HB-1	Redstone	18.2	14.8	14.8	18.3	142	366	489	362	192	92.1	46.4	29.0	149
	10EA-2	Flat	0.384	0.362	0.303	0.311	2.12	9.22	8.86	5.45	2.76	1.40	0.762	0.440	2.75
	10EA-3	Flat	18.0	16.2	14.7	19.4	168	297	218	149	107	66.2	29.0	21.5	98.8
	10EB-1	South Nahanni	32.2	28.5	25.9	31.1	235	854	613	389	229	133	60	40	232
	10EC-1	South Nahanni	72.2	62.2	56.1	70.5	586	1 400	1 030	733	468	267	127	91	433
	10EC-2	Prairie Creek	0.379	0.285	0.214	0.639	12.1	18.4	13.7	9.46	6.51	2.91	1.33	0.65	5.85
	10GA-1	Root	9.47	8.58	8.12	15.2	193	212	221	187	124	71.5	24.6	12.0	89.1
	10LA-2	Arctic Red	13.0	11.3	10.3	12.2	329	477	296	404	193	75.0	24.6	15.9	154
	10ED-1	Liard	381	334	308	513	3 110	6 310	4 900	3 020	2 270	1 640	697	446	1 990
	10ED-2	Liard	474	435	413	535	3 700	7 750	6 170	3 850	2 760	1 880	771	538	2 440
Interior Plains	10LC-3	Rengleng	0.253	0.018	0.001	0.064	23.7	19.0	4.38	3.30	2.69	1.65	0.583	0.186	4.66
	10LC-7	Caribou Creek	0.033	0.006	0.001	0.007	6.04	6.79	3.39	1.85	1.58	0.727	0.505	0.223	1.75
	10KC-1	Anderson	26.4	18.5	13.5	13.4	299	567	267	164	180	110	59.6	39.0	132
	10JC-3	Great Bear	519	510	500	486	508	554	586	595	593	565	539	524	540
	10JB-1	Johnny Hoe	5.35	3.78	3.36	3.73	141	117	63.5	32.2	25.9	20.9	12.3	8.11	36.7
	10GB-1	Willowlake	6.83	5.31	4.42	9.46	286	156	62.2	49.1	43.3	31.7	12.1	7.44	54.7
	10GC-2	Harris	0.003	0.002	0.001	0.915	7.40	1.92	0.442	0.186	0.251	0.312	0.036	0.006	1.03
	10GC-3	Martin	0.160	0.111	0.081	1.28	34.4	12.6	5.34	5.24	3.23	2.26	0.635	0.258	5.48
	10ED-3	Birch	0.029	0.016	0.008	3.09	10.9	2.82	1.18	2.61	2.26	1.39	0.215	0.046	1.67
	10FB-5	Jean-Marie	0.243	0.179	0.139	1.85	18.8	10.4	3.67	1.84	1.73	1.38	0.645	0.333	3.39
	10FA-2	Trout	0.683	0.413	0.429	10.7	108	108	57.3	34.4	29.9	19.2	4.88	1.33	33.4
	7UC-1	Kakisa	18.8	14.0	10.7	10.4	45.8	98.7	72.0	48.5	44.0	46.9	36.9	26.5	38.6
	70B-1	Hay	5.21	3.13	2.35	62.9	415	270	183	130	97.1	70.9	32.5	11.7	106
	7FA-1	Buffalo	3.57	0.402	0.038	8.06	126	149	110	88.7	69.3	51.0	18.6	12.6	46.7
Canadian Shield	7QA-1	Taltson	161	137	116	102	152	216	230	211	189	183	184	175	163
	7QC-3	Thoa	18.3	13.7	11.0	11.8	59.6	67.2	56.3	43.3	42.5	42.2	37.8	27.5	34.7
	7SB-9	Baker Creek	0.021	0.012	0.002	0.082	0.730	0.630	0.226	0.083	0.084	0.099	0.059	0.031	0.168
	7SB-3	Yellowknife	27.4	23.5	21.8	18.5	25.0	34.5	42.7	43.5	42.2	37.8	34.5	30.2	31.6
	7SA-3	Snare	32.5	26.4	22.4	19.5	34.3	53.8	93.8	78.3	61.0	51.0	44.8	38.2	46.3
	7RD-1	Lockhart	117	104	91.6	83.4	83.4	103	127	146	150	145	134	119	117
	10JA-2	Camsell	80.8	74.6	69.0	63.4	68.6	95.6	110	106	102	94.7	90.6	86.8	86.8
	10PB-1	Coppermine	65.3	51.9	43.2	38.0	44.3	123	204	196	162	130	106	83.2	104
	10PC-1	Kendall	0.001	0.000	0.000	0.000	2.56	84.0	33.5	16.1	13.1	6.9	1.47	0.189	12.4

Table A-2
Monthly Flow Data - Extended Record - 2

Region	WSC Station Number	River Name	Monthly Discharge (m^3/s) Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean Annual (m^3/s)
Canadian Shield (Contd)	1QQA-1	Tree	9.98	7.52	5.91	5.61	8.00	49.2	99.7	78.3	55.7	38.2	23.2	14.2	33.0
	1GQD-1	Ellice	0.350	0.124	0.017	0.000	0.000	297	299	74.6	70.9	20.3	3.88	1.01	73.1
	1QRC-1	Back	61.8	47.4	39.6	33.9	37.6	943.4	2 010	911	723	433	197	97	460
	6JC-2	Thelon	24.8	17.4	13.2	14.1	118	741	462	328	374	209	93	39	196
	6MA-3	Thelon	326	265	244	254	377	1 870	1 960	1 100	916	679	509	495	757
	6JB-1	Hanbury	4.39	3.31	3.00	3.06	9.54	74.2	58.8	30.5	22.1	19.8	12.4	7.7	19.4
	6KC-3	Dubawnt	243	219	205	209	226	446	509	475	453	378	324	269	325
	6LA-1	Kazan	88.9	81.8	76.5	75.8	94.2	181	180	160	169	133	115	99	121
	6LC-1	Kazan	110	86.7	75.7	90.7	204	986	1 090	782	592	423	275	173	416
	6MA-2	Kingyouk Creek	0.000	0.000	0.000	0.000	1.67	18.2	4.71	2.14	2.58	0.63	0.002	0.000	2.49
	6MB-1	Quoich	4.34	3.11	3.34	4.72	23.5	433	635	212	255	103	36.5	11.1	144
	1QSB-1	Hayes	0.002	0.002	0.001	0.001	1.68	280	445	291	244	25.9	0.535	0.002	106
	1QTA-1	Freshwater Creek	0.001	0.001	0.001	0.001	0.001	2.84	23.4	8.07	3.76	0.880	0.030	0.001	3.25

TABLE A-3

MEAN ANNUAL PRECIPITATION

Station Name	1941 to 1980 Number of Years of Data	1941 to 1980 Precipitation (mm)	1962 to 1980 Number of Years of Data	1962 to 1980 Precipitation (mm)
Aklavik	33	236	-	-
Alert	27	154	16	175
Arctic Bay	30	127	5	125
Baker Lake	31	212	18	225
Brevoort Island	12	563	10	625
Brochet	35	432	14	439
Broughton Island	16	290	13	292
Byron Bay	16	102	12	102
Cambridge Bay	36	133	17	135
Cape Dyer	21	537	19	537
Cape Hooper	14	262	2	111
Cape Parry	19	141	6	110
Cape Warwick	8	386	-	-
Cape Young	15	153	11	132
Chesterfield	48	250	18	233
Churchill	39	376	18	334
Clinton Point	14	178	1	85
Clyde	35	191	18	168
Cowtwoyto	21	246	18	221
Coppermine	48	214	18	198
Coral Harbour	35	257	17	253
Dewar Lakes	17	226	13	221
Ennadai Lake	29	282	17	305
Eureka	28	59	14	57
Fort Good Hope	25	284	7	298
Fort McPherson	42	338	9	355
Fort Norman	40	333	-	-
Fort Providence	18	263	-	-
Fort Reliance	32	221	19	242
Fort Resolution	36	304	12	332
Fort Simpson	46	330	18	305
Fort Smith	36	324	18	323
Fort Vermillion	34	355	4	314
Frobisher Bay	34	382	18	351
Gladman Point	16	117	12	113
Hall Beach	23	186	19	197
Hay River	36	319	18	302
Holman	25	163	7	185
Inuvik	24	240	19	245
Isachsen	30	107	16	119

Table A-3
Mean Annual Precipitation - 2

Station Name	1941 to 1980 Number of Years of Data	1941 to 1980 Precipitation (mm)	1962 to 1980 Number of Years of Data	1962 to 1980 Precipitation (mm)
Jenny Lind Island	14	96	11	109
Lady Franklin	15	130	9	112
Longstaff Bluff	15	186	11	217
Mackar Inlet	16	172	12	172
Mould Bay	32	90	18	96
Nicholson Penn.	16	108	12	110
Norman Wells	36	313	18	290
Nottingham Island	40	270	8	284
Pelly Bay	13	192	-	-
Pond Inlet	18	145	3	140
Port Radium	24	227	4	239
Resolute	32	130	18	124
Resolution Island	28	309	-	-
Sachs Harbour	23	108	17	113
Shepherd Bay	13	137	9	118
Snare Rapids	19	250	3	250
Spence Bay	15	153	7	112
Tuktoyaktuk	18	130	14	130
Wrigley	25	333	10	362
Yellowknife	38	242	19	225

TABLE A-4

PHYSIOGRAPHIC AND CLIMATIC CHARACTERISTICS
OF RIVERS IN THE NORTHWEST TERRITORIES

Region	WSC Station Number	River Name	Physiographic						Climatic		
			Drainage Area	Proportion of Lake Area			Stream Slope	Length	Annual Mean Daily Temp	Mean February Temp	Mean Annual Precip
				On-Channel	Off-Channel	Total					
			(km^2)					(km)	(^oC)	(^oC)	(mm)
Cordilleran	9FD-1	Porcupine	55 400	0.0001	0.033	0.0331	0.00093	450	-10.5 c	-28.5	not listed because of innaccuracy in mountainous regions
	10MA-1	Peel	25 700	0.0001	0.0004	0.0005	0.0017	265	-8.0	-26.0	
	10MC-2	Peel	70 700	0.0001	0.004	0.0041	0.0012	505	-8.5	-26.5	
	9BB-1	South MacMillan	997	0.0001	0.020	0.0201	0.0052	73	-4.5	-22.5	
	10HC-3	Big Smith Creek	938	0.006	0.019	0.025	0.00348	70	-6.0	-26.0	
	10HB-1	Redstone	15 400	0.0001	0.002	0.0021	0.0037	290	-6.0	-24.5	
	10EA-2	Flat	152	0.0001	0.0001	0.0002	0.0305	13	-6.0	-23.5	
	10EA-3	Flat	8 500	0.0001	0.004	0.0041	0.0037	208	-5.0	-23.0	
	10EB-1	South Nahanni	14 600	0.0001	0.001	0.0011	0.0022	329	-6.5	-24.0	
	10EC-1	South Nahanni	33 400	0.0001	0.001	0.0011	0.0014	454	-5.5	-23.0	
	10EC-2	Prairie Creek	500	0.0001	0.0001	0.0002	0.0087	80	-5.0	-23.5	
	10GA-1	Root	9 840	0.0001	0.017	0.0171	0.0053	205	-5.5	-24.0	
	10LA-2	Arctic Red	15 100	0.0001	0.005	0.0051	0.0026	320	-8.5	-26.5	
	10ED-1	Liard	222 000	0.002	0.058	0.060	0.0013	756	-2.5	-21.0	
	10ED-2	Liard	277 000	0.002	0.047	0.049	0.0010	1 040	-2.5	-21.5	
Interior Plains	10LC-3	Rengleng	1 440	0.067	0.080	0.147	0.00072	85	-9.0	-28.5	310
	10LC-7	Caribou Creek	663	0.121	0.154	0.275	0.00555	40	-9.5	-29.0	260
	10NC-1	Anderson	48 400	0.006	0.304	0.31	0.00054	420	-9.5	-29.0	245
	10JB-1	Johnny Hoe	13 500	0.0001	0.113	0.1131	0.00092	158	-6.5	-26.0	290
	10GB-1	Willowlake	21 600	0.0001	0.041	0.0411	0.00290	289	-5.5	-25.0	290
	10GC-2	Harris	570	0.018	0.007	0.025	0.00277	65	-4.5	-24.0	320
	10GC-3	Martin	2 040	0.0001	0.025	0.0251	0.00160	105	-4.0	-23.5	360
	10ED-3	Birch	500	0.001	0.004	0.0041	0.00508	50	-3.5	-22.5	380
	10FB-5	Jean-Marie	13 100	0.007	0.018	0.025	0.00139	100	-3.5	-23.0	340
	10FA-2	Trout	9 090	0.046	0.012	0.058	0.0020	152	-3.0	-21.5	380
	7UC-1	Kakisa	14 900	0.062	0.015	0.077	0.0010	306	-4.0	-22.5	340
	7OB-1	Hay	47 900	0.004	0.010	0.014	0.000304	982	-2.5	-20.0	420
	7PB-2	Little Buffalo	3 600	0.006	0.024	0.030	0.00036 e	145	-3.5	-22.0	360
	7PA-1	Buffalo	17 800	0.034	0.035	0.069	0.0035	293	-3.5	-22.0	340
	10JC-3	Great Bear	146 000	0.251	0.037	0.288	0.000095	606	-7.0	-27.0	260
Canadian Shield	7QC-3	Thoa	9 630	0.014	0.140	0.154	0.00059	270	-4.5	-25.0	300
	7SB-9	Baker Creek	144	0.15	0.065	0.215	0.0020 e	38	-7.5	-28.5	250
	7SB-10	Cameron	3 570	0.060	0.175	0.235	0.00078	130	-6.5	-27.5	250
	7RD-1	Lockhart	26 700	0.066	0.240	0.306	0.00019	410	-11.5	-29.5	250
	10JA-2	Camsell	31 100	0.060	0.204	0.264	0.000096	352	-9.5	-28.0	270
	10PB-1	Coppermine	20 300	0.064	0.261	0.325	0.000257	322	-12.0	-30.0	250

Table A-4
Physiographic and Climatic Characteristics of Rivers in the Northwest Territories - 2

Region	WSC Station Number	River Name	Physiographic						Climatic		
			Drainage Area	Proportion of Lake Area			Stream Slope	Length	Annual Mean Daily Temp	Mean February Temp	Mean Annual Precip
				On-Channel	Off-Channel	Total					
			(km^2)					(km)	(^oC)	(^oC)	(mm)
Canadian Shield (Contd)	10PC-1	Kendall	2 800	0.039	0.057	0.096	0.00095	72	-10.5	-30.0	215
	10QA-1	Tree	5 960	0.074	0.259	0.333	0.002250	196	-11.5	-30.5	210
	10RC-1	Back	98 200	0.014	0.155	0.169	0.000350	899	-13.0	-33.0	210
	6JC-2	Thelon	65 300	0.021	0.250	0.271	0.000630	570	-11.0	-30.5	250
	6MA-3	Thelon	154 000	0.057	0.193	0.250	0.000385	1 146	-11.0	-31.0	270
	6KC-3	Dubawnt	67 900	0.076	0.144	0.220	0.000440	816	-9.0	-30.0	280
	6LA-1	Kazan	23 900	0.096	0.230	0.326	0.000180	262	-7.0	-27.5	340
	6LC-1	Kazan	72 300	0.072	0.183	0.255	0.000440	819	-10.5	-31.0	280
	6MA-2	Kingyouk Creek	433	0.035	0.126	0.161	0.00370	40	-11.5	-33.0	230
	6NB-1	Quoich	28 700	0.017	0.245	0.232	0.000775	295	-12.5	-34.5	210
	10SB-1	Hayes	17 700	0.004	0.099	0.103	0.000810	206	-14.0	-35.5	180
	10TA-1	Freshwater Creek	1 490	0.035	0.302	0.337	0.000790	58	-14.5	-34.5	140

e - estimated

TABLE A-5

FLOW CHARACTERISTICS OF RIVERS
IN THE NORTHWEST TERRITORIES

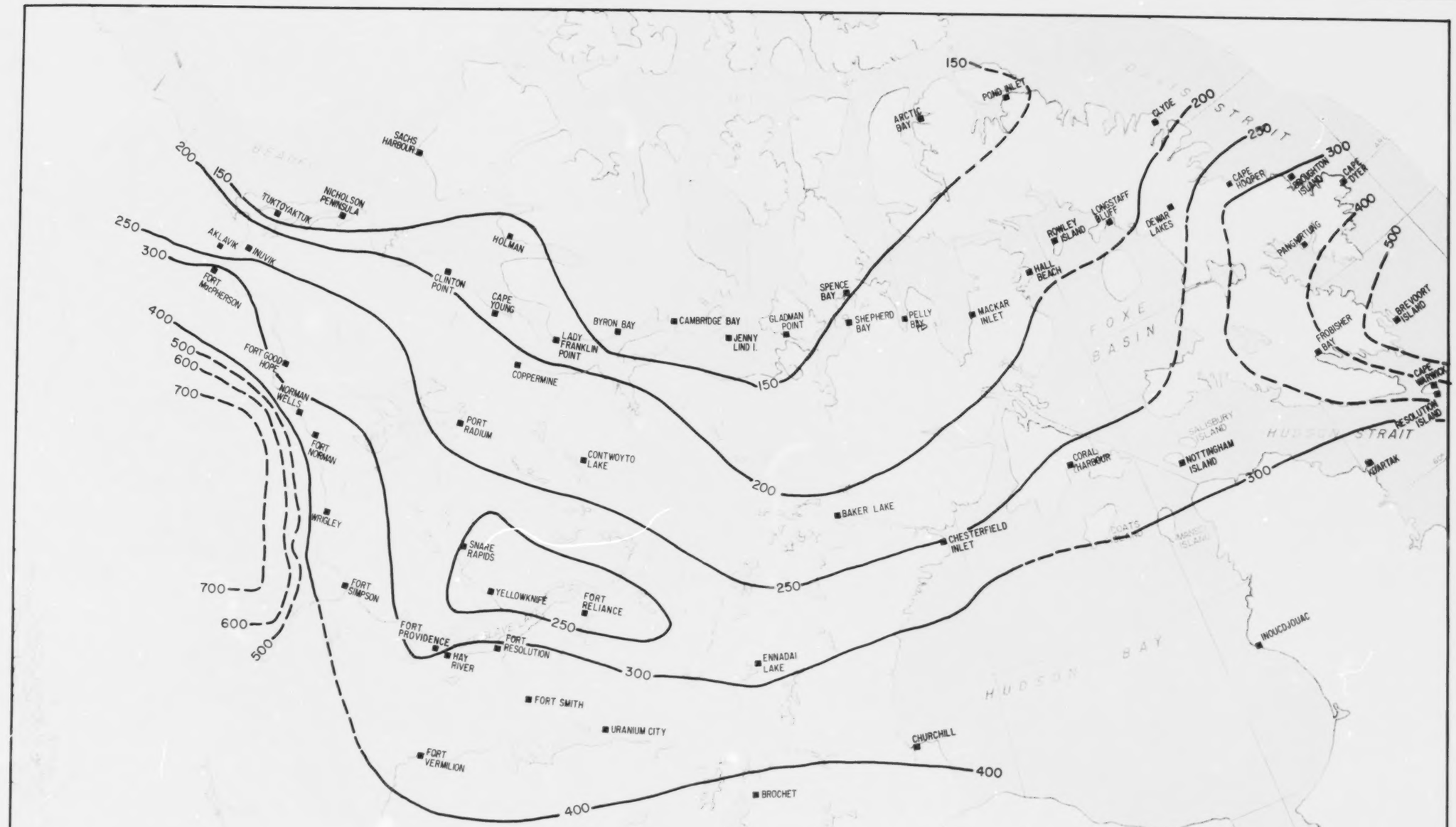
Region	WSC Station Number	River Name	Annual Mean Flow (m^3/s)	Runoff (mm)	Cv*	Flood Flow (m^3/s) Mean Annual	Flood Flow (m^3/s) Return Period (Years) 5	10	20	Low Flow (m^3/s) Mean Annual	Low Flow (m^3/s) Return Period (Years) 5	10	20
Cordilleran	9FD-1	Porcupine	346	197	0.234	4 484	5 830	6 480	6 960	15.6	13.1	12.1	11.1
	10MA-1	Peel	197	242	0.292	2 278	3 080	3 860	4 650	17.3	15.4	14.8	14.0
	10MC-2	Peel	792	353	0.162	6 516	8 660	10 400	12 200	64	49	42	37
	9HB-1	South MacMillan	21	665	0.137	109	126	134	140	1.30	0.66	0.50	0.40
	10HC-3	Big Smith Creek	5.53	186	0.397	117	165	216	271	INSF**	INSF	INSF	INSF
	10HB-1	Redstone	149	305	0.089	1 041	1 370	1 630	1 880	INSF	INSF	INSF	INSF
	10EA-2	Flat	2.75	570	0.064	18	22	24	26	INSF	INSF	INSF	INSF
	10EA-3	Flat	99	367	0.125	668	834	959	1 080	14.3	11.8	10.6	9.8
	10EB-1	South Nahanni	232	502	0.126	1 442	1 700	1 880	2 040	25.0	22.0	20.5	19.2
	10EC-1	South Nahanni	433	409	0.157	2 491	3 110	3 600	4 070	54.6	44.0	39.0	35.5
	10EC-2	Prairie Creek	5.85	373	0.193	42	57	69	82	INSF	INSF	INSF	INSF
	10GA-1	Root	89	286	0.209	1 203	1 680	2 170	2 690	5.87	2.95	2.15	1.65
	10LA-2	Arctic Red	154	321	0.175	1 167	1 400	1 560	1 710	9.76	8.2	7.5	7.0
	10ED-1	Liard	1 995	284	0.175	9 925	12 300	13 700	14 800	292	240	215	200
	10ED-2	Liard	2 440	278	0.155	12 170	15 500	18 000	20 400	394	340	320	300
Interior Plains	10LC-3	Rengleng	4.66	102	0.602	64	139	265	465	0	0	0	0
	10LC-7	Caribou Creek	1.75	83	0.343	36	64	98	140	0	0	0	0
	10NC-1	Anderson	132	86	0.415	1 062	1 450	1 820	2 200	INSF	INSF	INSF	INSF
	10JC-3	Great Bear	540	117	0.080	571	701	755	792	485	460	445	430
	10JB-1	Johnny Hoe	37	86	0.245	329	565	825	1 150	3.05	1.90	1.55	1.30
	10GB-1	Willowlake	55	80	0.294	622	812	969	1 120	3.33	2.05	1.65	1.38
	10GC-2	Harris	1.03	57	0.648	18	32	48	68	0	0	0	0
	10GC-3	Martin	5.48	85	0.367	83	110	125	140	0.077	0.015	0	0
	10ED-3	Birch	1.87	117	0.553	39	65	92	122	INSF	INSF	INSF	INSF
	10FB-5	Jean-Marie	3.39	82	0.406	42	70	103	143	0.127	0.070	0.053	0.042
	10FA-2	Trout	33	116	0.419	201	302	402	509	0.438	0.088	0.047	0.029
	7UC-1	Kakisa	39	82	0.428	121	189	262	343	9.65	7.3	6.4	5.8
	7UB-1	Hay	106	70	0.511	741	1 000	1 200	1 410	2.12	0.80	0.56	0.42
	7PB-2	Little Buffalo	INSF	INSF	INSF	15	21	27	33	INSF	INSF	INSF	INSF
	7PA-1	Buffalo	47	83	0.446	197	246	282	315	0.020	0	0	0
Canadian Shield	7QA-1	Taltson	163	83	0.328	Regulated							
	7QC-3	Thoa	35	114	0.241	92	121	147	171	9.5	7.2	6.2	5.4
	7SB-9	Baker Creek	0.17	37	0.597	1.22	1.6	2.1	2.6	0	0	0	0
	7SB-3	Yellowknife	32	89	0.365	Regulated							
	7SB-10	Cameron	INSF	INSF	INSF	7.0	11.6	17	23	INSF	INSF	INSF	INSF
	7SA-3	Snare	46	96	0.255	Regulated							
	7RD-1	Lockhart	117	139	0.166	158	183	200	216	80	68	63	58
	10JA-2	Carsell	87	88	0.197	117	139	155	169	58.9	48.0	43.0	40.5
	10PB-1	Coppermine	104	161	0.162	215	254	269	280	35.8	33.0	31.0	29.0

Table A-5
Flow Characteristics of Rivers
in the Northwest Territories - 2

Region	WSC Station Number	River Name	Annual Mean Flow (m^3/s)	Runoff (mm)	Cv*	Flood Flow (m^3/s) Mean Annual	Return Period (Years) 5	10	20	Low Flow (m^3/s) Mean Annual	Return Period (Years) 5	10	20
Canadian Shield (contd)	10PC-1	Kendall	12	140	0.187	126	190	245	300	INSF**	INSF	INSF	INSF
	10QA-1	Tree	33	175	0.125	120	141	156	170	4.9	3.3	2.8	2.4
	10QD-1	Ellice	73	136	0.094	INSF	INSF	INSF	INSF	INSF	INSF	INSF	INSF
	10RC-1	Back	460	148	0.199	3 631	4 340	4 830	5 280	24.9	20.0	17.0	15.0
	6JC-2	Thelon	196	95	0.224	1 256	1 560	1 780	1 990	10.0	7.6	6.9	6.3
	6MA-3	Thelon	757	155	0.064	3 072	3 390	3 600	3 710	233	190	175	160
	6JB-1	Hanbury	19	144	0.412	INSF	INSF	INSF	INSF	INSF	INSF	INSF	INSF
	6KC-3	Dubawnt	325	151	0.121	616	708	768	821	178	160	150	140
	6LA-1	Kazan	121	159	0.295	227	291	343	392	71	52	44	39
	6LC-1	Kazan	416	181	0.194	1 549	1 780	1 920	2 050	68	36	28	23
	6MA-2	Kingyouk Creek	2.49	182	0.344	50	69	85	102	0	0	0	0
	6MB-1	Quoich	144	158	0.172	1 282	1 640	1 920	2 190	2.49	0.92	0.62	0.45
	10SB-1	Hayes	106	189	0.343	1 565	2 210	2 900	3 620	0	0	0	0
	10TA-1	Freshwater Creek	3.25	69	0.223	43	52	58	64	INSF	INSF	INSF	INSF

* Cv - Coefficient of variation
**INSF - Insufficient Data

PLATES



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200 — 200 MILLIMETRE PRECIPITATION ISOHYET (DASHED LINE OVER AREAS WHERE DATA ARE SPARSE OR NOT AVAILABLE)

JENNY LIND I ■ — PRECIPITATION STATION USED IN PREPARATION OF MAP

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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

MAINLAND
MEAN ANNUAL PRECIPITATION
PERIOD 1941-1980

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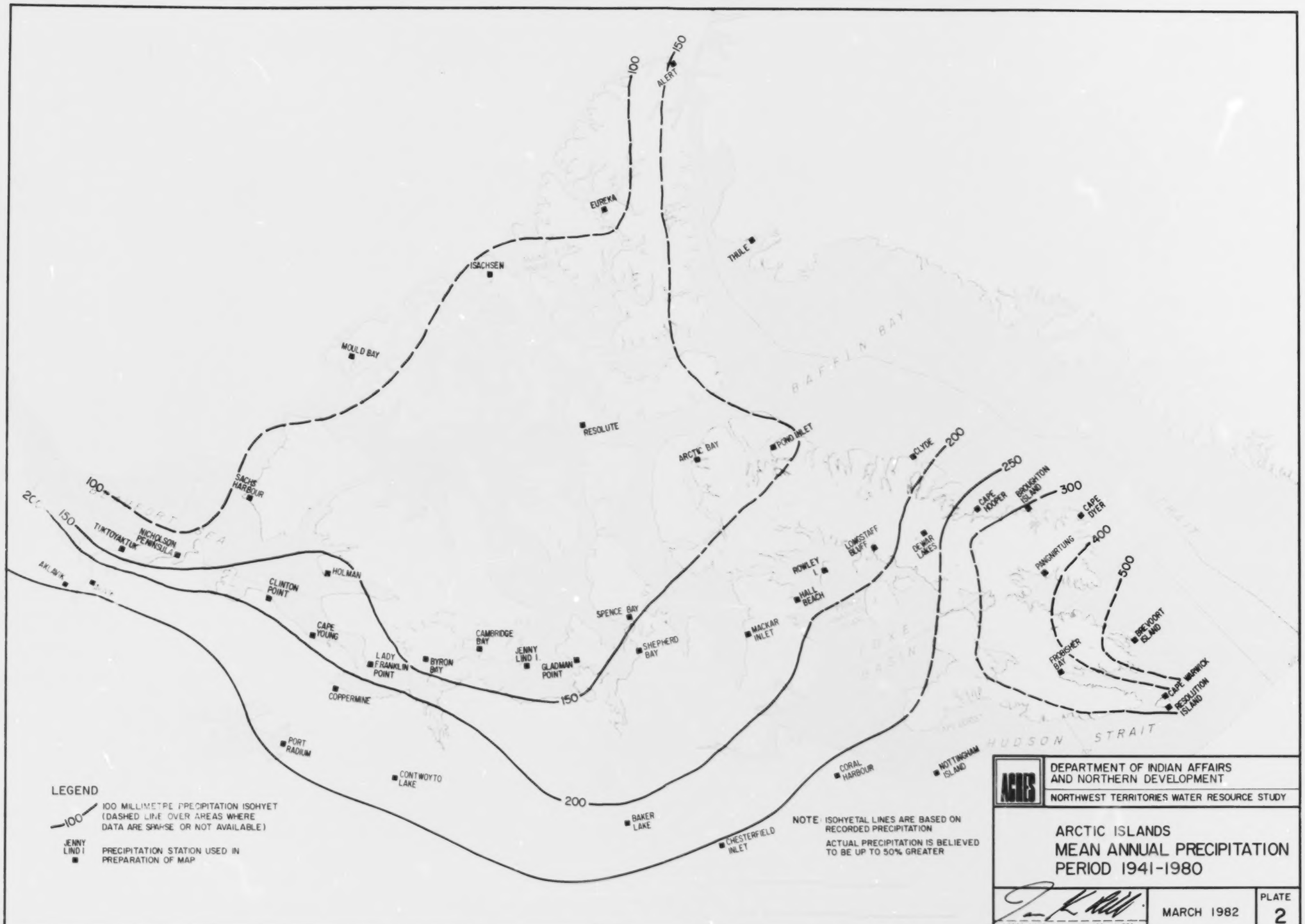
MARCH 1982

PLATE 1



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PERIOD 1941-1980

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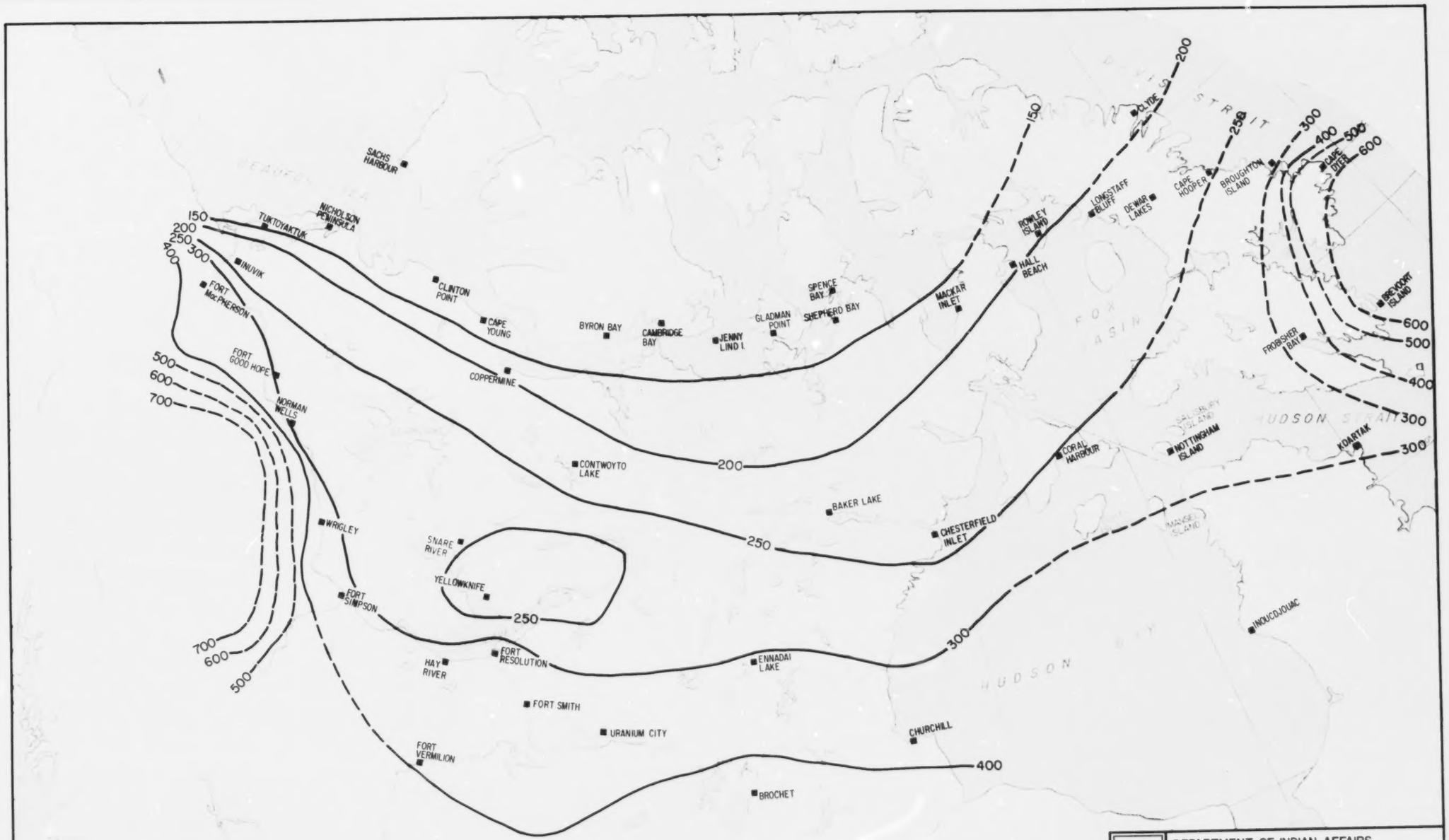
PLATE 2



LEGEND

100 — 100 MILLIMETRE PRECIPITATION ISOHYET (DASHED LINE OVER AREAS WHERE DATA ARE SPARSE OR NOT AVAILABLE)

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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

MAINLAND MEAN ANNUAL PRECIPITATION PERIOD 1962-1980

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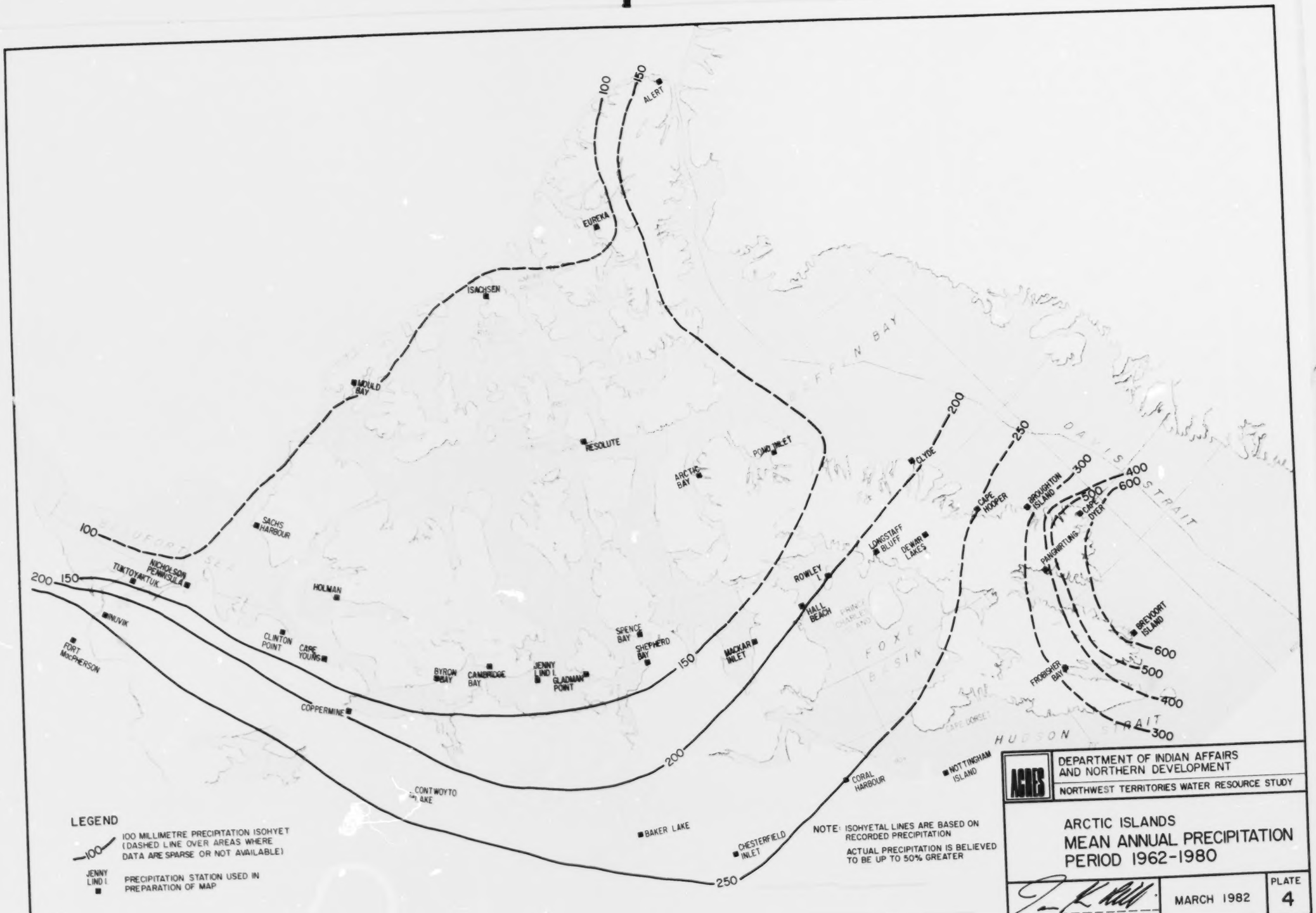
PLATE 3


100
150
200
250
300
400
500
600
ALERT
EUREKA
ISACHSEN
MOULD BAY
RESOLUTE
POND INLET
ARCTIC BAY
CLYDE
CAPE HOOPER
BROUGHTON ISLAND
CAPE DYER
PANGNIRTUNG
FROBISHER BAY
BREVOORT ISLAND
SACHS HARBOUR
NICHOLSON PENINSULA
TUKTOYAKTUK
HOLMAN
INUVIK
FORT MACPHERSON
CLINTON POINT
CAPE YOUNG
COPPERMINE
BYRON BAY
CAMBRIDGE BAY
JENNY LIND I.
GLADMAN POINT
SPENCE BAY
SHEPHERD BAY
MACKAR INLET
LONGSTAFF BLUFF
DEWAR LAKES
ROWLEY I.
HALL BEACH
CORAL HARBOUR
NOTTINGHAM ISLAND
CONTWOYTO LAKE
BAKER LAKE
CHESTERFIELD INLET
FOX BASIN
HUDSON STRAIT
FOXE BASIN
LEGEND
100 MILLIMETRE PRECIPITATION ISOHYET (DASHED LINE OVER AREAS WHERE DATA ARE SPARSE OR NOT AVAILABLE)
JENNY LIND I.
PRECIPITATION STATION USED IN PREPARATION OF MAP
NOTE: ISOHYETAL LINES ARE BASED ON RECORDED PRECIPITATION
ACTUAL PRECIPITATION IS BELIEVED TO BE UP TO 50% GREATER
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NORTHWEST TERRITORIES WATER RESOURCE STUDY
ARCTIC ISLANDS
MEAN ANNUAL PRECIPITATION
PERIOD 1962-1980
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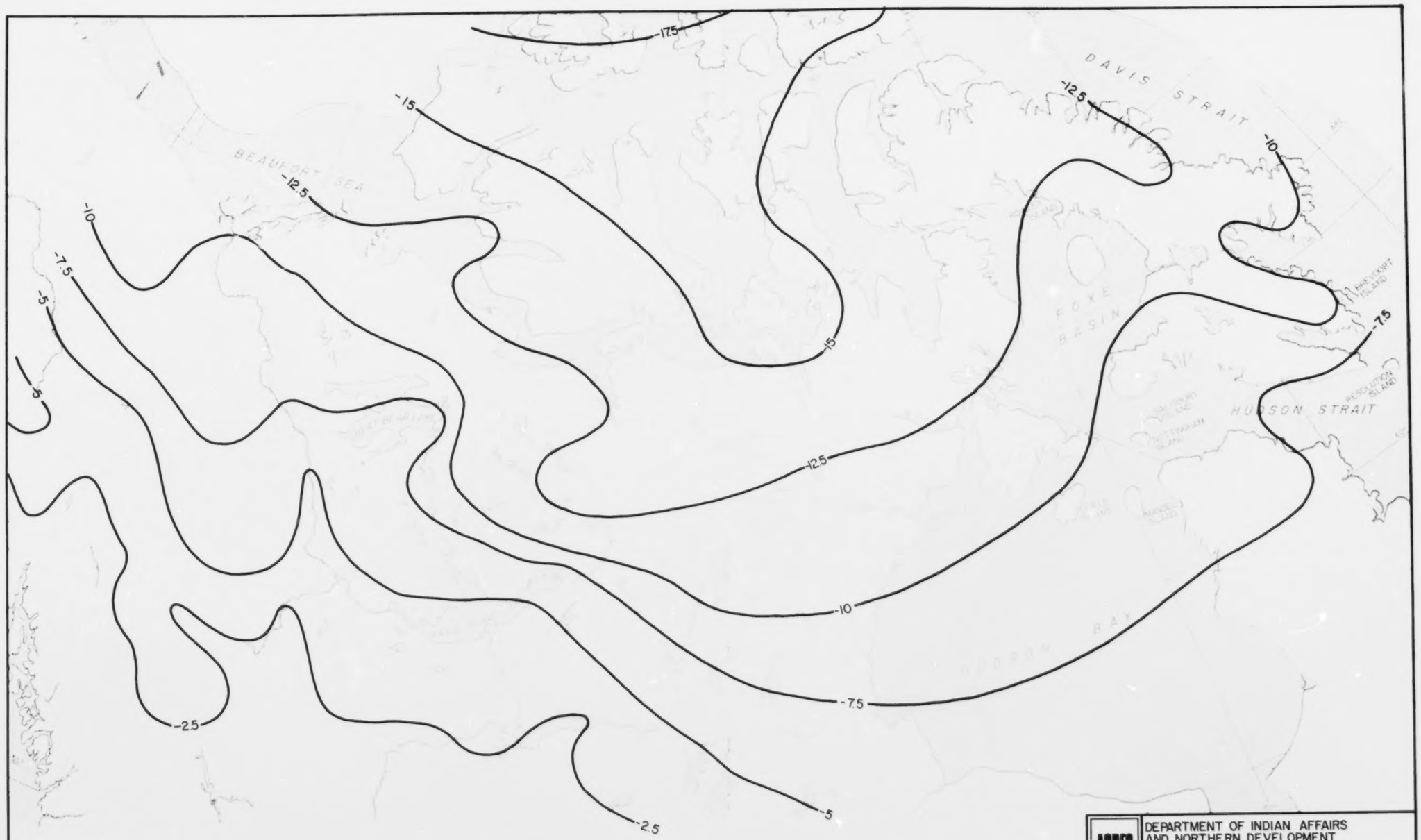
MARCH 1982
PLATE 4



LEGEND

—5— ISOTHERM OF ANNUAL MEAN DAILY TEMPERATURE (°C)

SOURCE "CLIMATIC MAPS - PERIOD 1931-1960",
CANADA DEPARTMENT OF TRANPORT,
METEOROLOGICAL BRANCH, OTTAWA, 1967

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NORTHWEST TERRITORIES WATER RESOURCE STUDY

MAINLAND
ANNUAL MEAN DAILY TEMPERATURE-PERIOD 1931-1960

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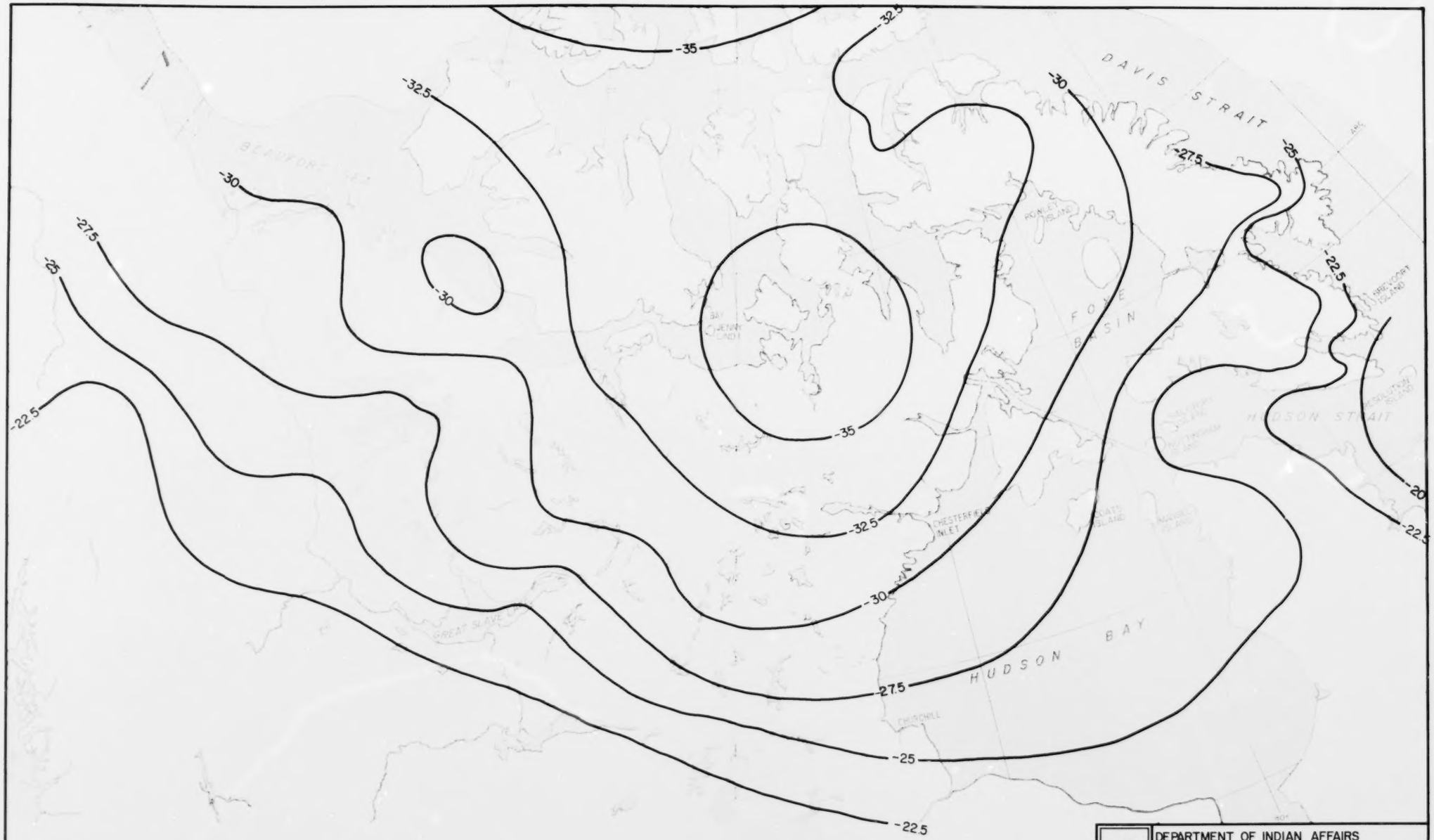
PLATE 5



LEGEND

—30— ISOTHERMS OF FEBRUARY MEAN DAILY TEMPERATURE (°C)

SOURCE "CLIMATIC MAPS - PERIOD 1931 - 1960"
CANADA DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH, OTTAWA, 1967

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MAINLAND
FEBRUARY MEAN DAILY TEMPERATURE-PERIOD 1931-1960

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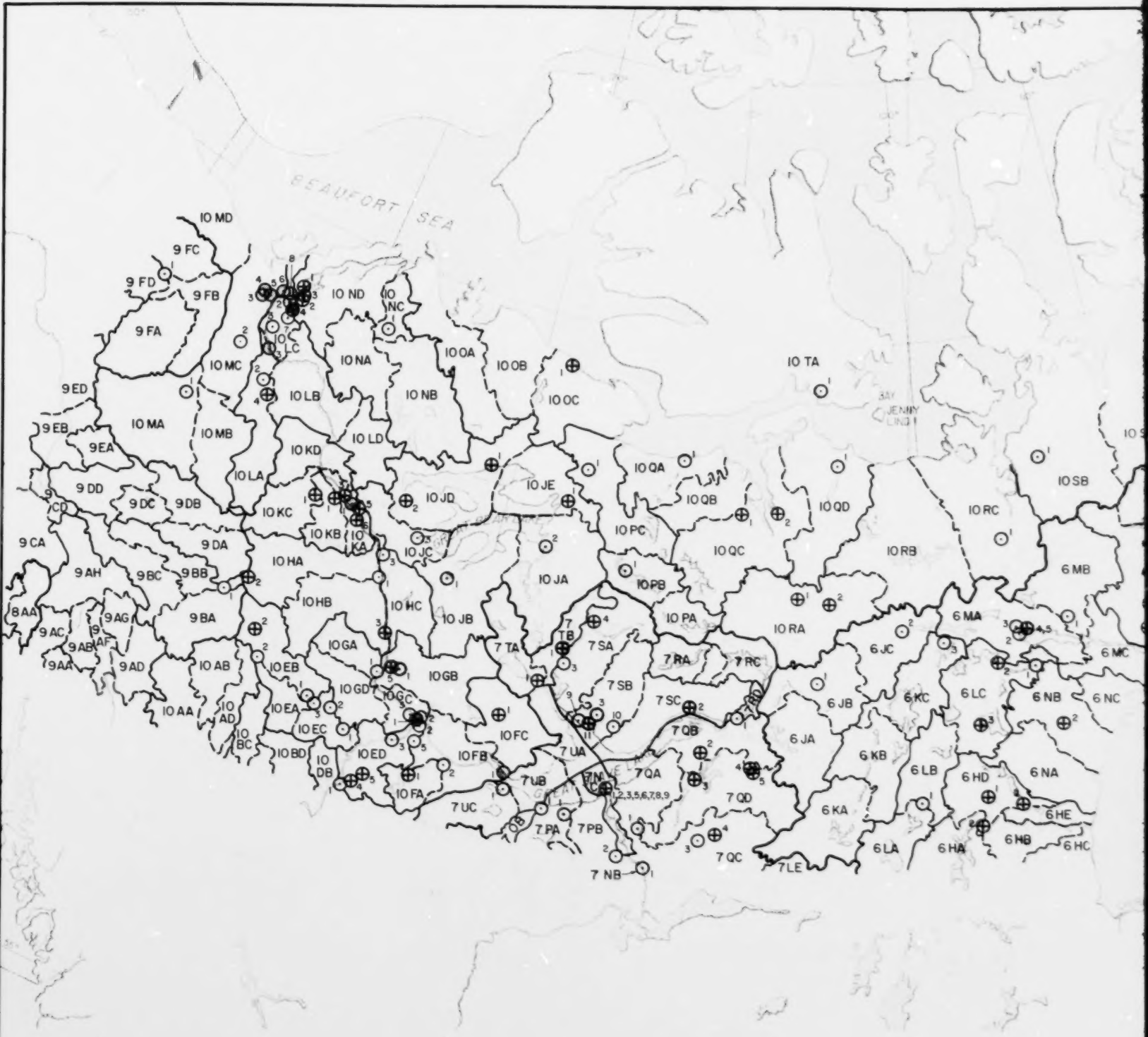
PLATE 6

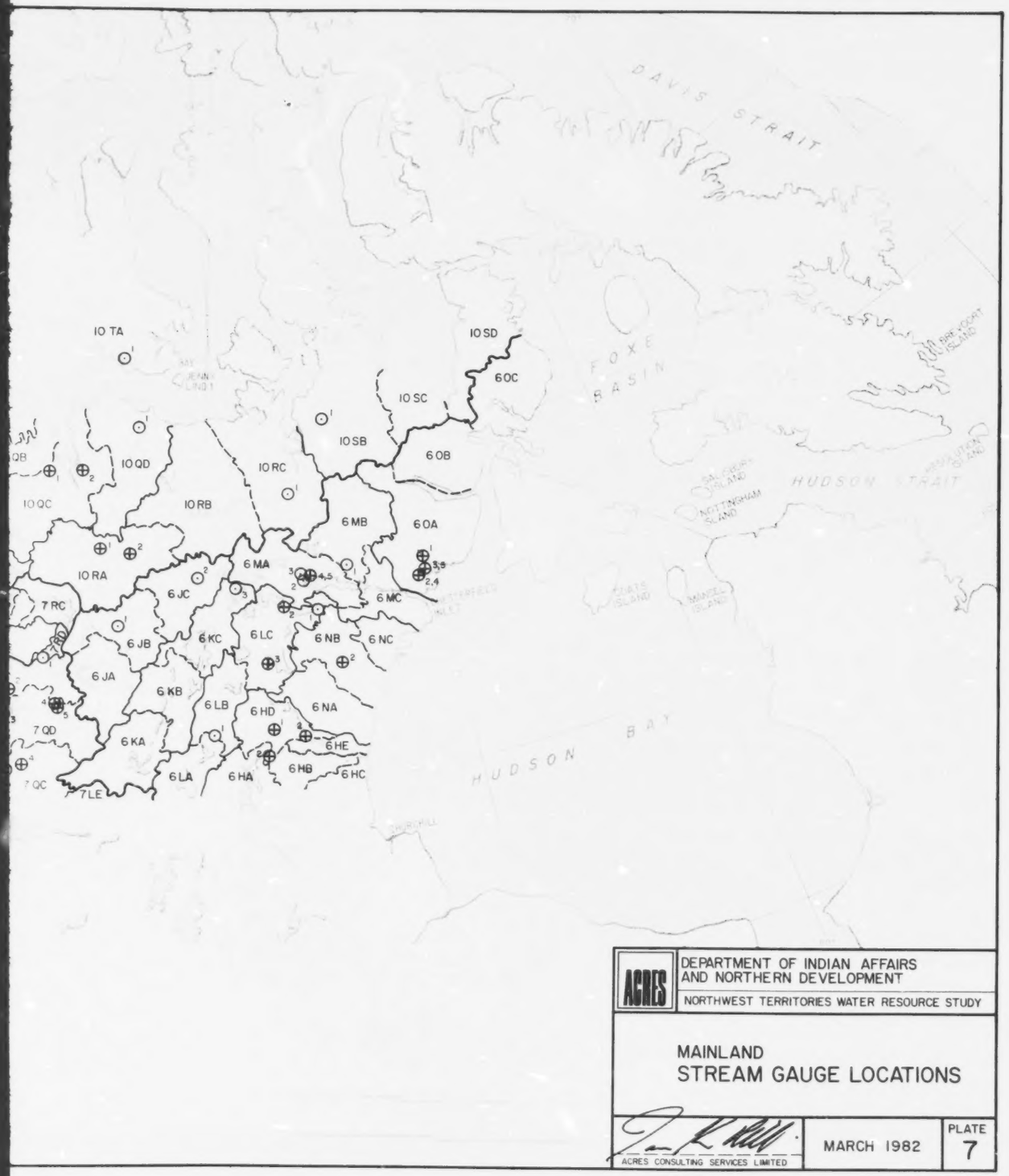
REGION	WSC STATION NUMBER	RIVER
CORDILLERAN REGION	9 FD - 1	PORCUPINE AT OLD CROW
	10 MA - 1	PEEL ABOVE CANYON CREEK
	10 MC - 2	PEEL ABOVE FORT MCPHERSON
	9 BB - 1	SOUTH MACMILLAN AT CANOL
	10 HC - 3	BIG SMITH CREEK NEAR MAC. HWY
	10 HB - 1	REDSTONE NEAR MOUTH
	10 EA - 2	FLAT AT CANTUNG CAMP
	10 EA - 3	FLAT NEAR MOUTH
	10 EB - 1	SOUTH NAHANNI ABOVE VIRGINIA FALLS
	10 EC - 1	SOUTH NAHANNI ABOVE CLAUSEN CREEK
	10 EC - 2	PRAIRIE CREEK AT CADILLAC MINE
	10 GA - 1	ROOT NEAR MOUTH
	10 LA - 2	ARCTIC RED NEAR MOUTH
	10 ED - 1	LIARD AT FORT LIARD
	10 ED - 2	LIARD NEAR MOUTH
	10 KA - 3	BOSWORTH CREEK AT NORMAN WELLS
	10 KB - 1	CARCAJOU BELOW IMPERIAL RIVER
	10 EB - 2	MAC CREEK NEAR THE MOUTH
	10 KC - 1	MOUNTAIN BELOW CAMBRIAN CREEK
	10 KA - 5	SEEPAGE CREEK AT NORMAN WELLS
	10 HA - 2	TSICHU AT CANOL ROAD
	10 LA - 4	WELDON CREEK NEAR THE MOUTH
	10 HB - 3	WRIGLEY NEAR THE MOUTH
	10 KA - 6	JUNGLE RIDGE CREEK NEAR THE MOUTH
INTERIOR PLAINS REGION	10 LC - 3	RENGLENG BELOW DEMPSTER HWY
	10 LC - 7	CARIBOU CREEK ABOVE DEMPSTER HWY
	10 NC - 1	ANDERSON BELOW CARNWATH RIVER
	10 JC - 3	GREAT BEAR AT OUTLET OF GREAT BEAR LAKE
	10 JB - 1	JOHNNY HOE ABOVE LAC STE. THERESE
	10 GB - 1	WILLOWLAKE NEAR THE MOUTH
	10 GC - 2	HARRIS NEAR THE MOUTH
	10 GC - 3	MARTIN NEAR THE MOUTH
	10 ED - 3	BIRCH AT FORT LIARD HWY
	10 FB - 5	JEAN-MARIE AT FORT SIMPSON HWY
	10 FA - 2	TROUT AT FORT SIMPSON HWY
	7 UC - 1	KAKISA AT OUTLET OF KAKISA LAKE
	7 OB - 1	HAY NEAR HAY RIVER
	7 PA - 1	BUFFALO AT HWY 5
	7 PB - 2	LITTLE BUFFALO NEAR PINE POINT HWY
	10 LC - 4	CAMPBELL CREEK NEAR INUVIK
	10 JD - 1	HALDANE NEAR THE MOUTH
	10 ND - 1	HANS CREEK NEAR INUVIK
	10 OC - 1	INMAN NEAR THE MOUTH
	7 TA - 1	LAMARTRE BELOW OUTLET OF LAC LA MARTRE
	10 FC - 1	PLATEAU CREEK NEAR WILLOW LAKE
	10 ED - 4	RABBIT CREEK AT FORT LIARD HWY
	10 ND - 2	RYAN CREEK NEAR INUVIK
	10 FA - 1	TROUT NEAR OUTLET OF TROUT LAKE
	10 GB - 5	UNNAMED TRIBUTARY TO WILLOWLAKE RIVER
	10 JD - 2	WHITEFISH NEAR THE MOUTH
	10 ND - 3	ZED CREEK NEAR INUVIK
	10 LC - 9	CABIN CREEK ABOVE DEMSTER HWY
	7 NC - 1	JEAN BELOW SLAVE RIVER
	7 NC - 2	NAGLE CHANNEL BELOW SLAVE RIVER
	7 NC - 8	SLAVE (EAST CHANNEL) NEAR FORT RESOLUTION
	7 NC - 7	SLAVE (MIDDLE CHANNEL EAST) NEAR FT. RESOLUTION
	7 NC - 6	SLAVE (MIDDLE CHANNEL WEST) NEAR FT. RESOLUTION
	7 NC - 3	SLAVE (OLD STEAMBOAT CHANNEL) N. FT. RESOLUTION
	7 NC - 9	SLAVE (RESDELTA CHANNEL) NEAR FT. RESOLUTION
	7 NC - 5	SLAVE (WEST CHANNEL) NEAR FORT RESOLUTION
	10 ED - 5	UNNAMED CREEK AT FORT LIARD HWY

REGION	WSC STATION NUMBER	RIVER
CANADIAN SHIELD REGION	7 QD - 1	TALTSON AT OUTLET OF TSU LAKE
	7 QC - 3	THOA NEAR INLET TO HILL ISLAND LAKE
	7 SB - 9	BAKER CREEK NEAR YELLOWKNIFE
	7 SB - 3	YELLOWKNIFE AT INLET TO PROSPEROUS LAKE
	7 SB - 10	CAMERON BELOW REID LAKE
	7 SA - 3	SNARE AT BIGSPRUCE LAKE
	7 RD - 1	LOCKHART AT OUTLET OF ARTILLARY LAKE
	10 JA - 2	CAMSELL AT OUTLET OF CLUT LAKE
	10 PB - 1	COPPERMINE AT OUTLET OF POINT LAKE
	10 PC - 1	KENDALL NEAR OUTLET OF DISMAL LAKE
	10 QA - 1	TREE NEAR THE MOUTH
	10 QD - 1	ELLICE NEAR THE MOUTH
	10 RC - 1	BACK BELOW DEEP ROSE LAKE
	6 JC - 2	THELON ABOVE BEVERLY LAKE
	6 MA - 3	THELON ABOVE BAKER LAKE
	6 JB - 1	HANBURY ABOVE HOARE LAKE
	6 KC - 3	DUBAWNT BELOW MARJORIE LAKE
	6 LA - 1	KAZAN AT OUTLET OF ENNADAI LAKE
	6 LC - 1	KAZAN ABOVE KAZAN FALLS
	6 MA - 2	KINGYOUK CREEK NEAR BAKER LAKE
	6 MB - 1	QUOICH ABOVE ST. CLAIR FALLS
	10 SB - 1	HAYES ABOVE CHANTREY INLET
	6 MA - 4	AKKUTUAK CREEK NEAR BAKER LAKE
	10 RA - 1	BACK BELOW BEECHY LAKE
	10 RA - 2	BAILLE NEAR THE MOUTH
	10 QC - 1	BURNSIDE NEAR THE MOUTH
	7 TB - 1	EMILE AT OUTLET OF BASLER LAKE
	6 OA - 3	FAR CREEK AT FAR LAKE OUTLET
	6 NB - 2	FERGUSON BELOW O'NEIL LAKE
	10 QC - 2	GORDON NEAR THE MOUTH
	7 SA - 4	INDIN ABOVE CHALCO LAKE
	6 HD - 1	KOGNAK BELOW MOUNTAIN LAKE
	6 LC - 2	KUNWAK BELOW PRINCESS MARY LAKE
	6 OA - 1	LORILLARD ABOVE DALY BAY
	7 QC - 4	MARTEN ABOVE THOA RIVER
	6 OA - 2	MEADOW CREEK ABOVE SAQVAQJUAC INLET
	6 OA - 4	P/N LAKE OUTLET
	7 SB - 11	POCKET LAKE OUTFLOW NEAR YELLOWKNIFE
	7 QD - 5	PORTER LAKE OUTFLOW ABOVE TALTSON RIVER
	6 MA - 5	PRINCE NEAR BAKER LAKE
	6 OA - 5	SAQVAQJUAC ABOVE SAQVAQJUAC INLET
	10 JE - 1	SLOAN NEAR THE MOUTH
	7 QB - 2	SNOWDRIFT AT OUTLET OF SILTAZA LAKE
	6 LC - 3	SIURAQ CREEK NEAR OUTLET TO KAZAN RIVER
	7 QD - 4	TALTSON ABOVE PORTER LAKE OUTFLOW
	7 QD - 3	TALTSON NEAR OUTLET OF NONACHO LAKE
	6 HB - 2	THLEWIAZA BELOW SEAHOLE LAKE
	7 SC - 2	WALDRON NEAR THE MOUTH
	6 HD - 2	THA-ANNE BELOW SOUTH HENIK LAKE
MACKENZIE RIVER	10 MC - 5	MACKENZIE (AKLAVIK CH.) ABOVE SCHOONER CHAN.
	10 LC - 2	MACKENZIE (EAST CHANNEL) AT INUVIK
	10 LC - 6	MACKENZIE (KALINEK CH.) ABOVE ONIAK CHANNEL
	10 LC - 8	MACKENZIE (MIDDLE CH.) ABOVE NAPOIAK CHANNEL
	10 MC - 4	MACKENZIE (WEST CHANNEL) ABOVE AKLAVIK CHAN.
	10 MC - 3	MACKENZIE (PEEL CHANNEL) ABOVE AKLAVIK CHAN.
	10 LA - 3	MACKENZIE ABOVE ARCTIC RED RIVER
	10 GC - 1	MACKENZIE AT FORT SIMPSON
	10 KA - 1	MACKENZIE AT NORMAN WELLS
	10 FB - 1	MACKENZIE NEAR FORT PROVIDENCE



LEGEND

- ⊙$_1$ STATION NUMBER - STATION USED IN ANALYSES
- ⊕$_2$ STATION NUMBER - STATION NOT USED IN ANALYSES (INSUFFICIENT DATA)
- ⊙$_1$ STATION NUMBER - MACKENZIE RIVER



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NORTHWEST TERRITORIES WATER RESOURCE STUDY

MAINLAND
STREAM GAUGE LOCATIONS

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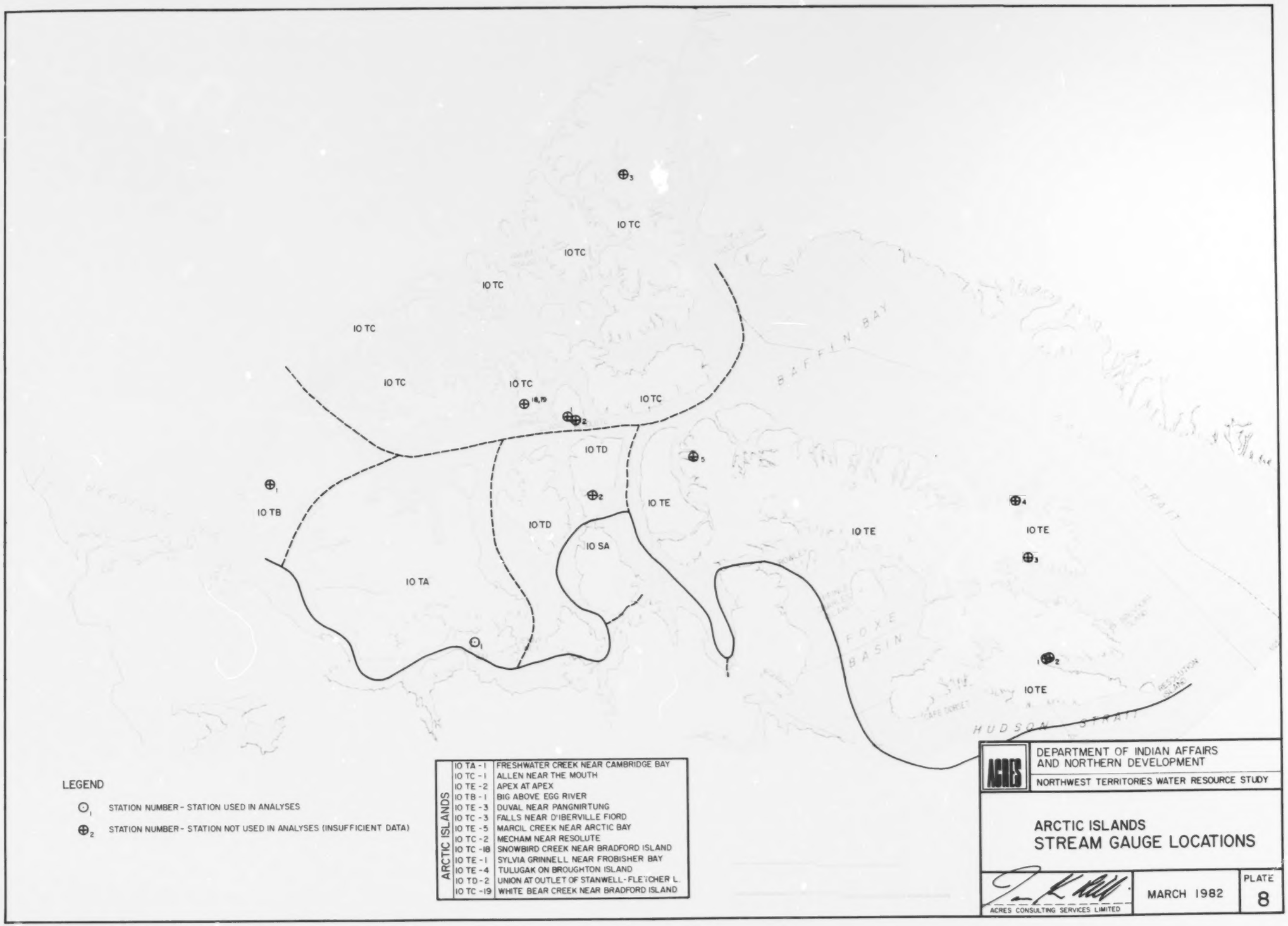
PLATE 7



LEGEND

$\odot_1$ STATION NUMBER - STATION USED IN ANALYSES

$\oplus_2$ STATION NUMBER - STATION NOT USED IN ANALYSES (INSUFFICIENT DATA)

ARCTIC ISLANDS	10 TA - 1	FRESHWATER CREEK NEAR CAMBRIDGE BAY
	10 TC - 1	ALLEN NEAR THE MOUTH
	10 TE - 2	APEX AT APEX
	10 TB - 1	BIG ABOVE EGG RIVER
	10 TE - 3	DUVAL NEAR PANGNIRTUNG
	10 TC - 3	FALLS NEAR D'IBERVILLE FIORD
	10 TE - 5	MARCIL CREEK NEAR ARCTIC BAY
	10 TC - 2	MECHAM NEAR RESOLUTE
	10 TC - 18	SNOWBIRD CREEK NEAR BRADFORD ISLAND
	10 TE - 1	SYLVIA GRINNELL NEAR FROBISHER BAY
	10 TE - 4	TULUGAK ON BROUGHTON ISLAND
	10 TD - 2	UNION AT OUTLET OF STANWELL-FLETCHER L.
	10 TC - 19	WHITE BEAR CREEK NEAR BRADFORD ISLAND

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NORTHWEST TERRITORIES WATER RESOURCE STUDY

ARCTIC ISLANDS STREAM GAUGE LOCATIONS

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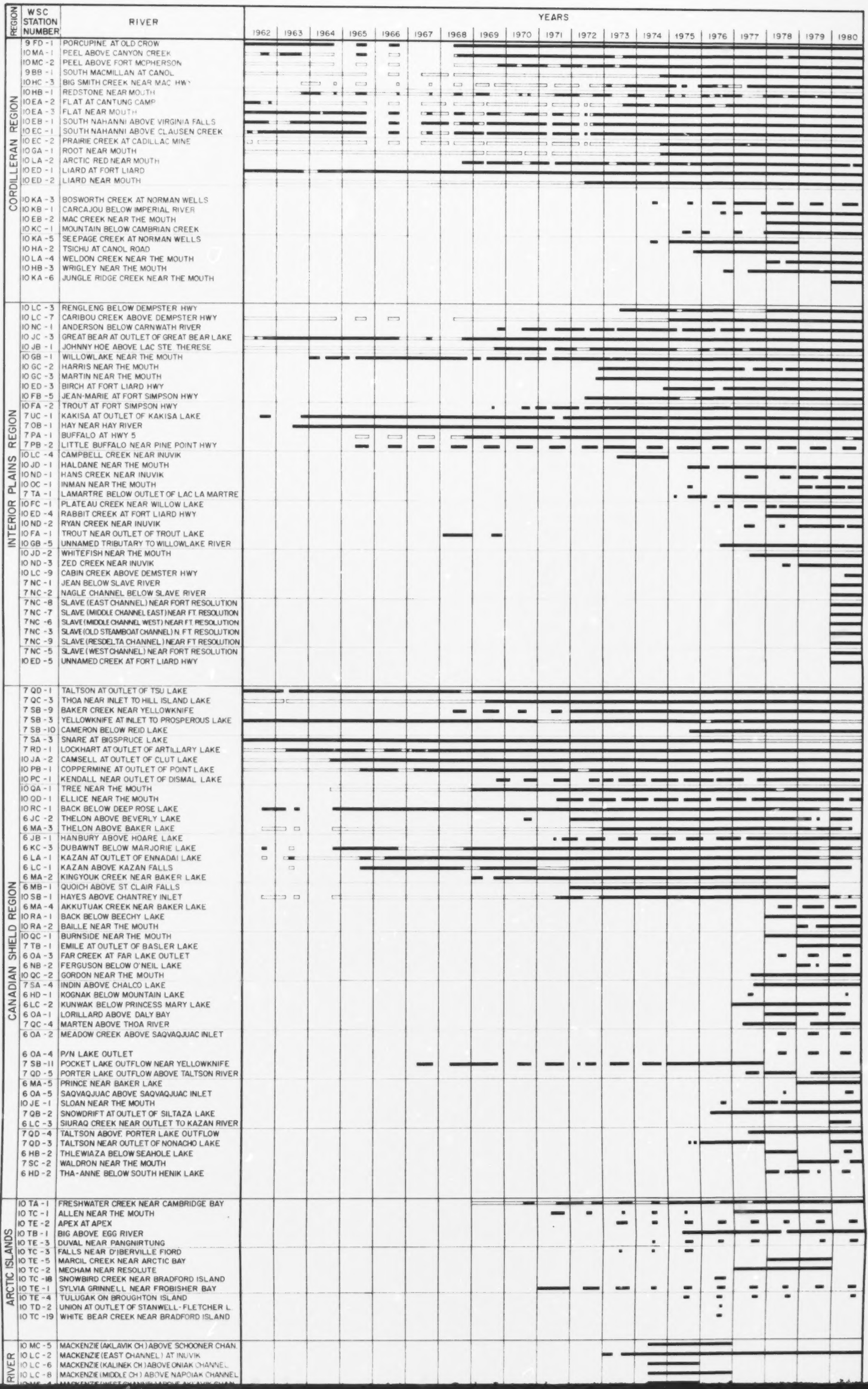
PLATE 8


REGION
WSC STATION NUMBER
RIVER
YEARS
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
CORDILLERAN REGION
9 FD -1 PORCUPINE AT OLD CROW
10 MA -1 PEEL ABOVE CANYON CREEK
10 MC -2 PEEL ABOVE FORT MCPHERSON
9 BB -1 SOUTH MACMILLAN AT CANOL
10 HC -3 BIG SMITH CREEK NEAR MAC HWY
10 HB -1 REDSTONE NEAR MOUTH
10 EA -2 FLAT AT CANTUNG CAMP
10 EA -3 FLAT NEAR MOUTH
10 EB -1 SOUTH NAHANNI ABOVE VIRGINIA FALLS
10 EC -1 SOUTH NAHANNI ABOVE CLAUSEN CREEK
10 EC -2 PRAIRIE CREEK AT CADILLAC MINE
10 GA -1 ROOT NEAR MOUTH
10 LA -2 ARCTIC RED NEAR MOUTH
10 ED -1 LIARD AT FORT LIARD
10 ED -2 LIARD NEAR MOUTH
10 KA -3 BOSWORTH CREEK AT NORMAN WELLS
10 KB -1 CARCAJOU BELOW IMPERIAL RIVER
10 EB -2 MAC CREEK NEAR THE MOUTH
10 KC -1 MOUNTAIN BELOW CAMBRIAN CREEK
10 KA -5 SEEPAGE CREEK AT NORMAN WELLS
10 HA -2 TSICHU AT CANOL ROAD
10 LA -4 WELDON CREEK NEAR THE MOUTH
10 HB -3 WRIGLEY NEAR THE MOUTH
10 KA -6 JUNGLE RIDGE CREEK NEAR THE MOUTH
INTERIOR PLAINS REGION
10 LC -3 RENGLENG BELOW DEMPSTER HWY
10 LC -7 CARIBOU CREEK ABOVE DEMPSTER HWY
10 NC -1 ANDERSON BELOW CARNWATH RIVER
10 JC -3 GREAT BEAR AT OUTLET OF GREAT BEAR LAKE
10 JB -1 JOHNNY HOE ABOVE LAC STE THERESE
10 GB -1 WILLOWLAKE NEAR THE MOUTH
10 GC -2 HARRIS NEAR THE MOUTH
10 GC -3 MARTIN NEAR THE MOUTH
10 ED -3 BIRCH AT FORT LIARD HWY
10 FB -5 JEAN-MARIE AT FORT SIMPSON HWY
10 FA -2 TROUT AT FORT SIMPSON HWY
7 UC -1 KAKISA AT OUTLET OF KAKISA LAKE
7 OB -1 HAY NEAR HAY RIVER
7 PA -1 BUFFALO AT HWY 5
7 PB -2 LITTLE BUFFALO NEAR PINE POINT HWY
10 LC -4 CAMPBELL CREEK NEAR INUVIK
10 JD -1 HALDANE NEAR THE MOUTH
10 ND -1 HANS CREEK NEAR INUVIK
10 OC -1 INMAN NEAR THE MOUTH
7 TA -1 LAMARTRE BELOW OUTLET OF LAC LA MARTRE
10 FC -1 PLATEAU CREEK NEAR WILLOW LAKE
10 ED -4 RABBIT CREEK AT FORT LIARD HWY
10 ND -2 RYAN CREEK NEAR INUVIK
10 FA -1 TROUT NEAR OUTLET OF TROUT LAKE
10 GB -5 UNNAMED TRIBUTARY TO WILLOWLAKE RIVER
10 JD -2 WHITEFISH NEAR THE MOUTH
10 ND -3 ZED CREEK NEAR INUVIK
10 LC -9 CABIN CREEK ABOVE DEMSTER HWY
7 NC -1 JEAN BELOW SLAVE RIVER
7 NC -2 NAGLE CHANNEL BELOW SLAVE RIVER
7 NC -8 SLAVE (EAST CHANNEL) NEAR FORT RESOLUTION
7 NC -7 SLAVE (MIDDLE CHANNEL EAST) NEAR FT RESOLUTION
7 NC -6 SLAVE (MIDDLE CHANNEL WEST) NEAR FT RESOLUTION
7 NC -3 SLAVE (OLD STEAMBOAT CHANNEL) N FT RESOLUTION
7 NC -9 SLAVE (RESDELTA CHANNEL) NEAR FT RESOLUTION
7 NC -5 SLAVE (WEST CHANNEL) NEAR FORT RESOLUTION
10 ED -5 UNNAMED CREEK AT FORT LIARD HWY
CANADIAN SHIELD REGION
7 QD -1 TALTSON AT OUTLET OF TSU LAKE
7 QC -3 THOA NEAR INLET TO HILL ISLAND LAKE
7 SB -9 BAKER CREEK NEAR YELLOWKNIFE
7 SB -3 YELLOWKNIFE AT INLET TO PROSPEROUS LAKE
7 SB -10 CAMERON BELOW REID LAKE
7 SA -3 SNARE AT BIGSPRUCE LAKE
7 RD -1 LOCKHART AT OUTLET OF ARTILLARY LAKE
10 JA -2 CAMSELL AT OUTLET OF CLUT LAKE
10 PB -1 COPPERMINE AT OUTLET OF POINT LAKE
10 PC -1 KENDALL NEAR OUTLET OF DISMAL LAKE
10 QA -1 TREE NEAR THE MOUTH
10 QD -1 ELLICE NEAR THE MOUTH
10 RC -1 BACK BELOW DEEP ROSE LAKE
6 JC -2 THELON ABOVE BEVERLY LAKE
6 MA -3 THELON ABOVE BAKER LAKE
6 JB -1 HANBURY ABOVE HOARE LAKE
6 KC -3 DUBAWNT BELOW MARJORIE LAKE
6 LA -1 KAZAN AT OUTLET OF ENNADAI LAKE
6 LC -1 KAZAN ABOVE KAZAN FALLS
6 MA -2 KINGYOUK CREEK NEAR BAKER LAKE
6 MB -1 QUOICH ABOVE ST CLAIR FALLS
10 SB -1 HAYES ABOVE CHANTREY INLET
6 MA -4 AKKUTUAK CREEK NEAR BAKER LAKE
10 RA -1 BACK BELOW BEECHY LAKE
10 RA -2 BAILLE NEAR THE MOUTH
10 QC -1 BURNSIDE NEAR THE MOUTH
7 TB -1 EMILE AT OUTLET OF BASLER LAKE
6 OA -3 FAR CREEK AT FAR LAKE OUTLET
6 NB -2 FERGUSON BELOW O'NEIL LAKE
10 QC -2 GORDON NEAR THE MOUTH
7 SA -4 INDIN ABOVE CHALCO LAKE
6 HD -1 KOGNAK BELOW MOUNTAIN LAKE
6 LC -2 KUNWAK BELOW PRINCESS MARY LAKE
6 OA -1 LORILLARD ABOVE DALY BAY
7 QC -4 MARTEN ABOVE THOA RIVER
6 OA -2 MEADOW CREEK ABOVE SAQVAQJUAC INLET
6 OA -4 P/N LAKE OUTLET
7 SB -11 POCKET LAKE OUTFLOW NEAR YELLOWKNIFE
7 QD -5 PORTER LAKE OUTFLOW ABOVE TALTSON RIVER
6 MA -5 PRINCE NEAR BAKER LAKE
6 OA -5 SAQVAQJUAC ABOVE SAQVAQJUAC INLET
10 JE -1 SLOAN NEAR THE MOUTH
7 QB -2 SNOWDRIFT AT OUTLET OF SILTAZA LAKE
6 LC -3 SIURAQ CREEK NEAR OUTLET TO KAZAN RIVER
7 QD -4 TALTSON ABOVE PORTER LAKE OUTFLOW
7 QD -3 TALTSON NEAR OUTLET OF NONACHO LAKE
6 HB -2 THLEWIAZA BELOW SEAHOLE LAKE
7 SC -2 WALDRON NEAR THE MOUTH
6 HD -2 THA-ANNE BELOW SOUTH HENIK LAKE
ARCTIC ISLANDS
10 TA -1 FRESHWATER CREEK NEAR CAMBRIDGE BAY
10 TC -1 ALLEN NEAR THE MOUTH
10 TE -2 APEX AT APEX
10 TB -1 BIG ABOVE EGG RIVER
10 TE -3 DUVAL NEAR PANGNIRTUNG
10 TC -3 FALLS NEAR D'IBERVILLE FIORD
10 TE -5 MARCIL CREEK NEAR ARCTIC BAY
10 TC -2 MECHAM NEAR RESOLUTE
10 TC -18 SNOWBIRD CREEK NEAR BRADFORD ISLAND
10 TE -1 SYLVIA GRINNELL NEAR FROBISHER BAY
10 TE -4 TULUGAK ON BROUGHTON ISLAND
10 TD -2 UNION AT OUTLET OF STANWELL-FLETCHER L.
10 TC -19 WHITE BEAR CREEK NEAR BRADFORD ISLAND
RIVER
10 MC -5 MACKENZIE (AKLAVIK CH.) ABOVE SCHOONER CHAN.
10 LC -2 MACKENZIE (EAST CHANNEL) AT INUVIK
10 LC -6 MACKENZIE (KALINEK CH.) ABOVE ONIAK CHANNEL
10 LC -8 MACKENZIE (MIDDLE CH.) ABOVE NAPOIAK CHANNEL

7 QB - 2 SNOWDRIFT AT OUTLET OF KAZAN LAKE
6 LC - 3 SIURAQ CREEK NEAR OUTLET TO KAZAN RIVER
7 QD - 4 TALTSON ABOVE PORTER LAKE OUTFLOW
7 QD - 3 TALTSON NEAR OUTLET OF MONACHO LAKE
6 HB - 2 THLEWIAZA BELOW SEAHOLE LAKE
7 SC - 2 WALDRON NEAR THE MOUTH
6 HD - 2 THA-ANNE BELOW SOUTH HENIK LAKE
ARCTIC ISLANDS
10 TA - 1 FRESHWATER CREEK NEAR CAMBRIDGE BAY
10 TC - 1 ALLEN NEAR THE MOUTH
10 TE - 2 APEX AT APEX
10 TB - 1 BIG ABOVE EGG RIVER
10 TE - 3 DUVAL NEAR PANGNIRTUNG
10 TC - 3 FALLS NEAR D'IBERVILLE FJORD
10 TC - 5 MARCIL CREEK NEAR ARCTIC BAY
10 TC - 2 MECHAM NEAR RESOLUTE
10 TC - 18 SNOWBIRD CREEK NEAR BRADFORD ISLAND
10 TE - 1 SYLVIA GRINNELL NEAR FROBISHER BAY
10 TE - 4 TULUGAK ON BROUGHTON ISLAND
10 TD - 2 UNION AT OUTLET OF STANWELL-FLETCHER L.
10 TC - 19 WHITE BEAR CREEK NEAR BRADFORD ISLAND
MACKENZIE RIVER
10 MC - 5 MACKENZIE (AKLAVIK CH.) ABOVE SCHOONER CHAN.
10 LC - 2 MACKENZIE (EAST CHANNEL) AT INUVIK
10 LC - 6 MACKENZIE (KALINEK CH.) ABOVE ONIAK CHANNEL
10 LC - 8 MACKENZIE (MIDDLE CH.) ABOVE NAPOIAK CHANNEL
10 MC - 4 MACKENZIE (WEST CHANNEL) ABOVE AKLAVIK CHAN.
10 MC - 3 MACKENZIE (PEEL CHANNEL) ABOVE AKLAVIK CHAN.
10 LA - 3 MACKENZIE ABOVE ARCTIC RED RIVER
10 GC - 1 MACKENZIE AT FORT SIMPSON
10 KA - 1 MACKENZIE AT NORMAN WELLS
10 FB - 1 MACKENZIE NEAR FORT PROVIDENCE
LEGEND
EXISTING DATA
EXTENDED DATA

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NORTHWEST TERRITORIES WATER RESOURCE STUDY

STREAM GAUGING STATIONS– PERIODS OF RECORD AND DATA EXTENSIONS

ACRES CONSULTING SERVICES LIMITED

MARCH 1982

PLATE 9

LEGEND

- CANADIAN SHIELD REGION
- INTERIOR PLAINS REGION
- CORDILLERAN REGION
- ARCTIC COAST LOWLANDS REGION

SOURCE: 1 CANADIAN GEOGRAPHIC JOURNAL SERIES D MAP No.1
2 NATIONAL ATLAS OF CANADA, 4th ed., TORONTO, MacMILLAN, 1974

- SOUTHERN LIMIT OF CONTINUOUS PERMAFROST ZONE
- APPROXIMATE NORTHERN LIMIT OF TREES

SOURCE: 1 CANADIAN GEOGRAPHIC JOURNAL SERIES D MAP No.1
2 DEPARTMENT OF ENERGY, MINES AND RESOURCES SURVEYS AND MAPPING BRANCH NORTHWEST TERRITORIES MAP - 1:4,000,000 SCALE, 1974

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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

MAINLAND PHYSIOGRAPHIC CHARACTERISTICS

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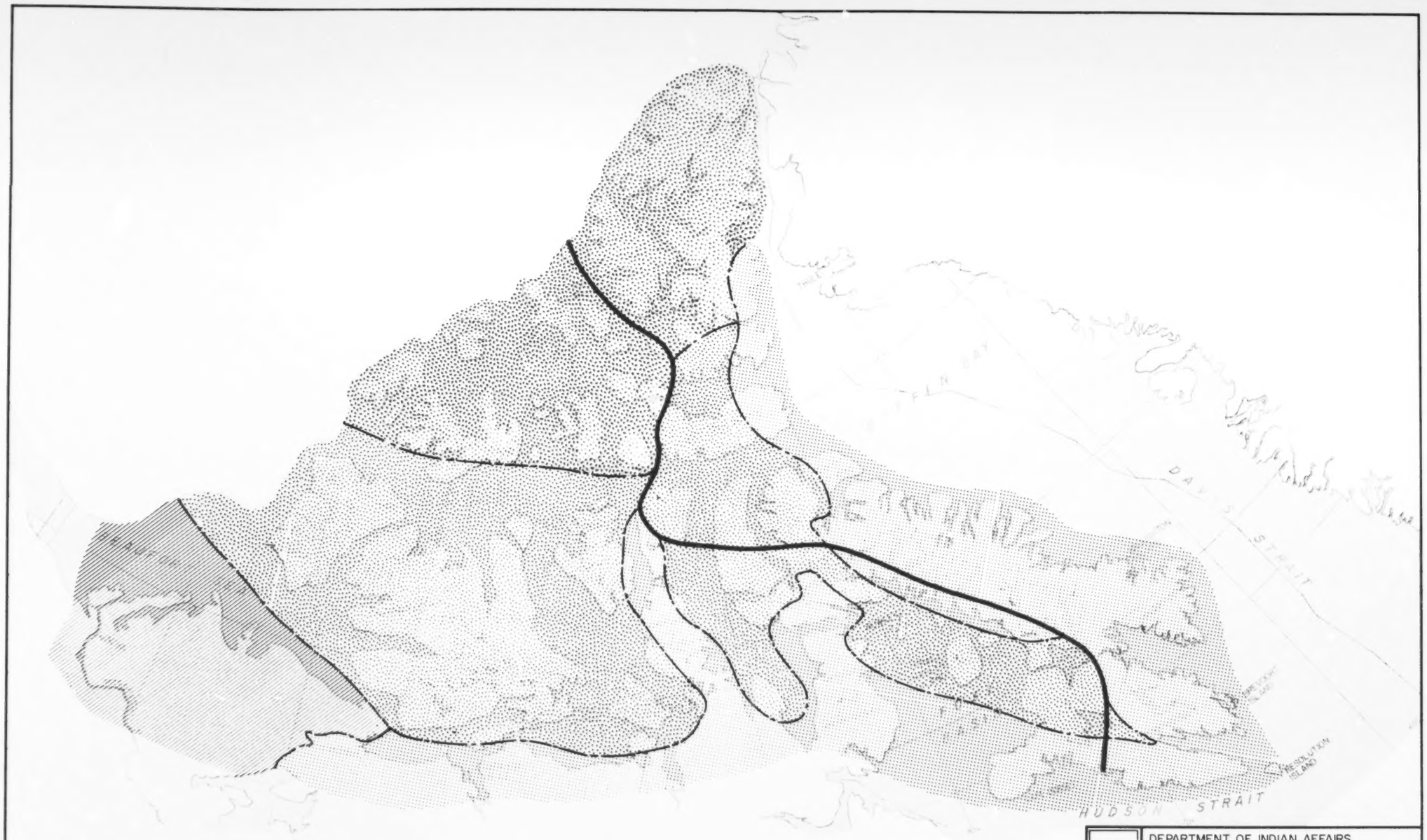
MARCH 1982

PLATE 10



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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

ARCTIC ISLANDS PHYSIOGRAPHIC CHARACTERISTICS

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PLATE 11

LEGEND

(100) — 100 MILLIMETRE RUNOFF ISOLINE

136e + ELLICE 10QD-1 — COMPUTED MEAN ANNUAL RUNOFF OF ELLICE BASIN IN MILLIMETRES (WSC STREAM GAUGE ID# 10QD-1)
- Point Plotted at Centroid of Basin
- e Indicates Runoff Computation Based on Less Than 10 Years Record

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NORTHWEST TERRITORIES WATER RESOURCE STUDY

MAINLAND
MEAN ANNUAL RUNOFF
PERIOD 1962-1980

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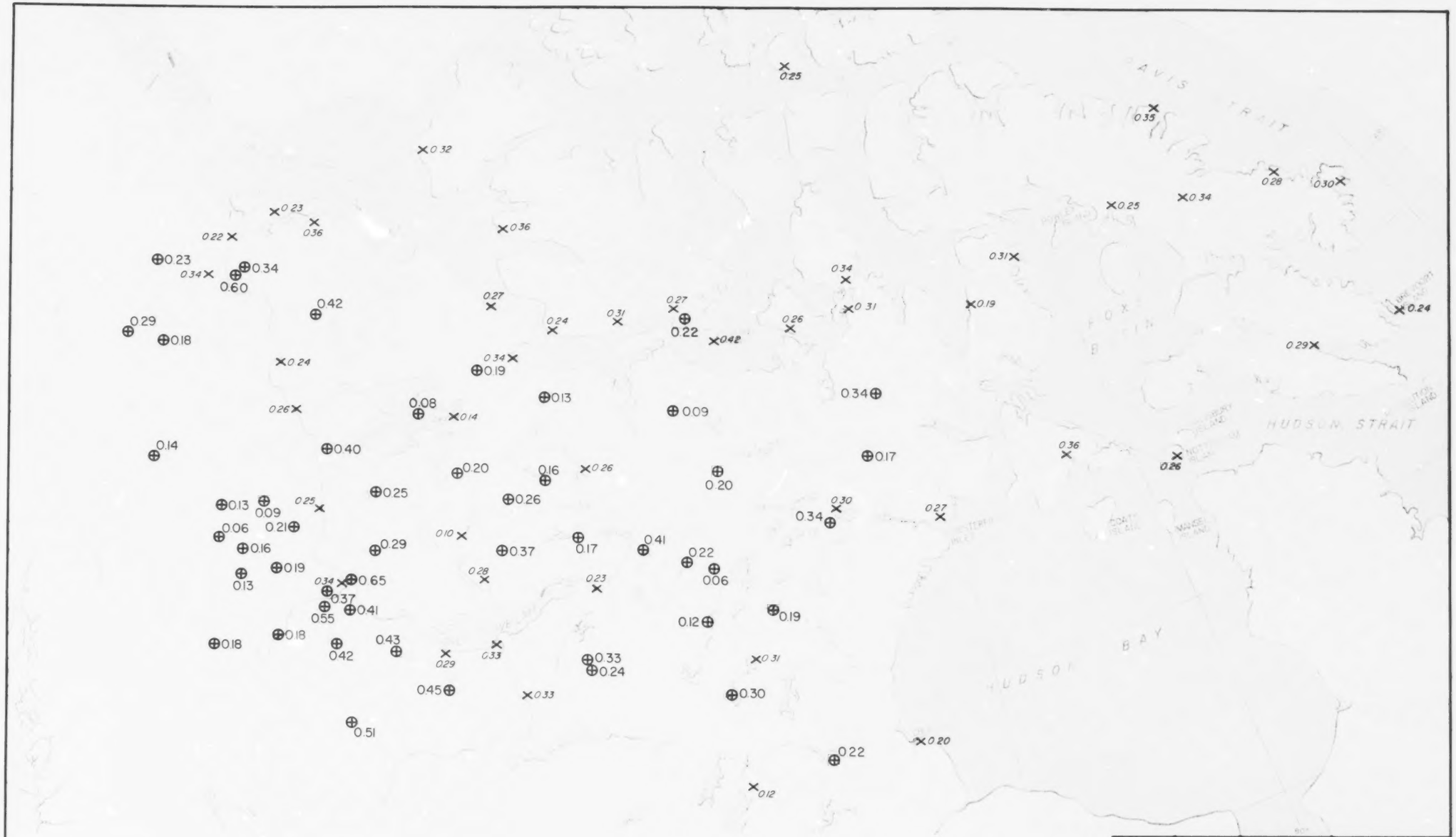
PLATE 12



LEGEND

⊕0.37 COEFFICIENT OF VARIATION OF ANNUAL RUNOFF

×0.21 COEFFICIENT OF VARIATION OF ANNUAL PRECIPITATION

NOTE

COEFFICIENT OF VARIATION $C_v = \frac{S}{\bar{X}}$

WHERE S = STANDARD DEVIATION OF SAMPLE

$\bar{X}$ = MEAN OF SAMPLE

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NORTHWEST TERRITORIES WATER RESOURCE STUDY

MAINLAND COEFFICIENTS OF VARIATION

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PLATE 13

LEGEND

$\times^{0.21}$ COEFFICIENT OF VARIATION OF ANNUAL PRECIPITATION

NOTE

COEFFICIENT OF VARIATION $Cv = \frac{S}{\bar{X}}$

WHERE S = STANDARD DEVIATION OF SAMPLE

$\bar{X}$ = MEAN OF SAMPLE

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

ARCTIC ISLANDS
COEFFICIENTS OF VARIATION

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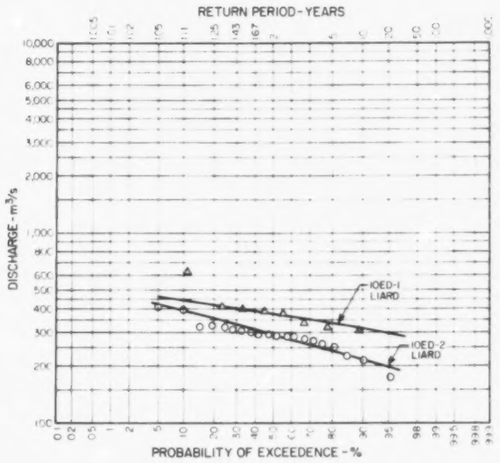
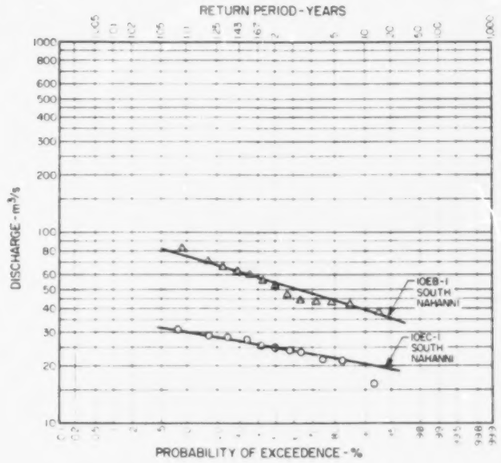
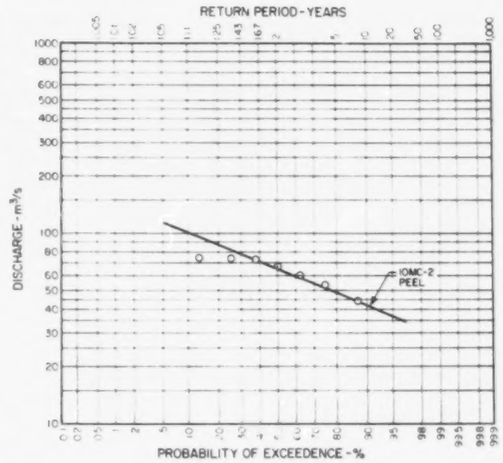
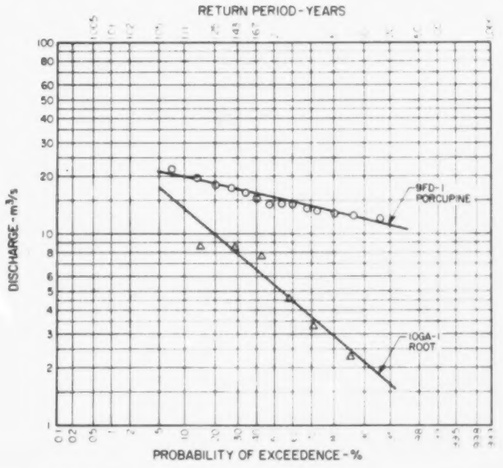
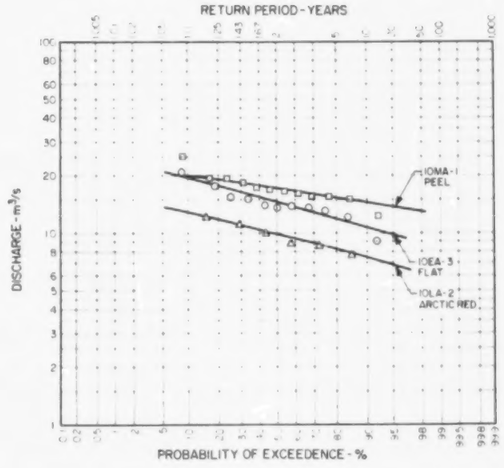
PLATE 14

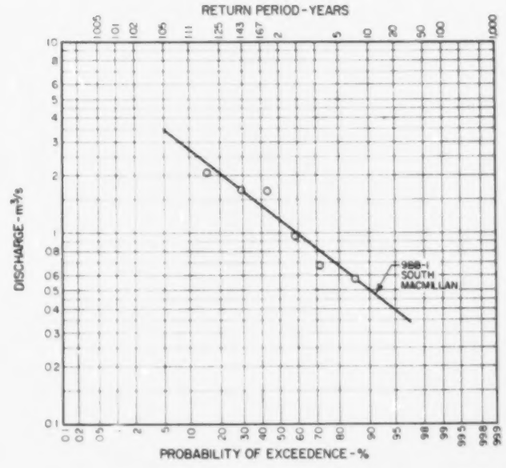












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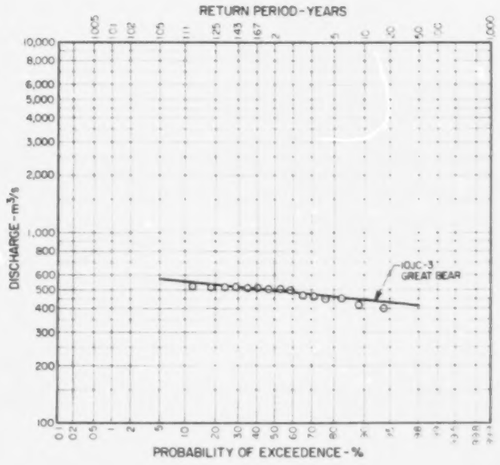
NORTHWEST TERRITORIES WATER RESOURCE STUDY

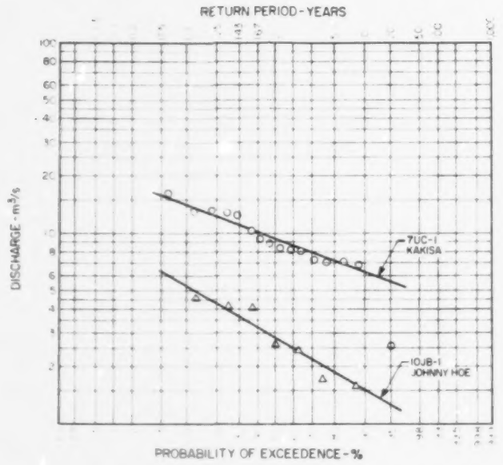
30-DAY LOW FLOW FREQUENCY CURVES- CORDILLERAN REGION

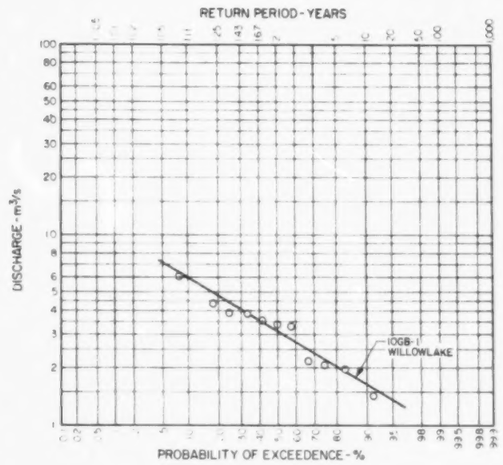
ACRES CONSULTING SERVICES LIMITED

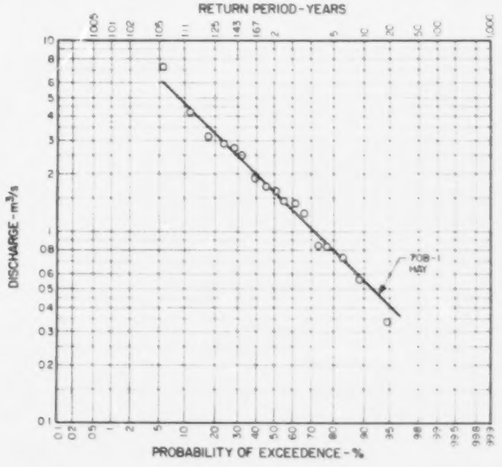
MARCH 1982

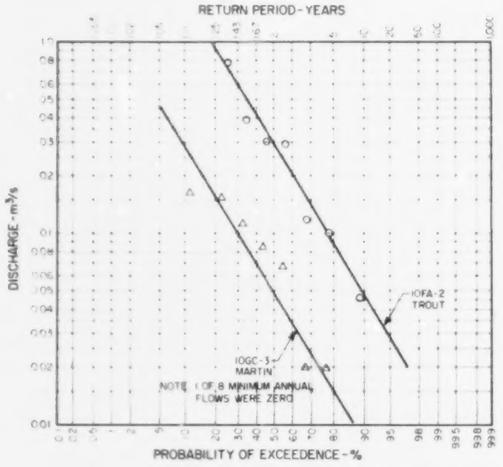
PLATE 15

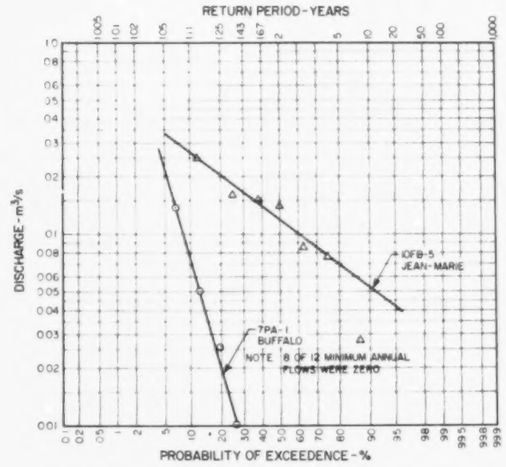












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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

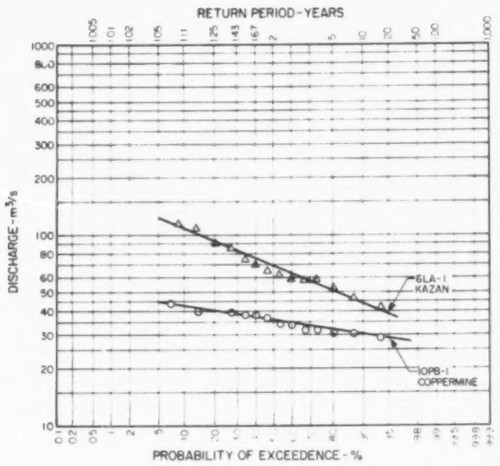
NORTHWEST TERRITORIES WATER RESOURCE STUDY

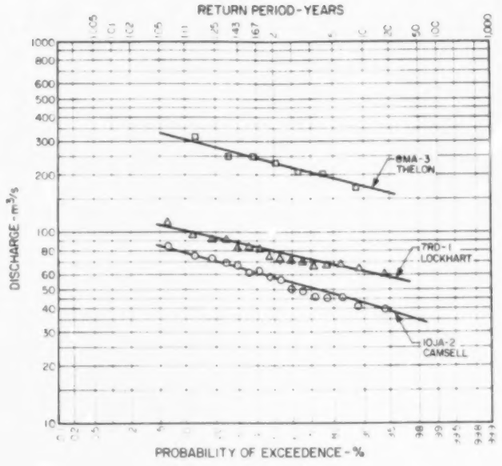
30-DAY LOW FLOW FREQUENCY CURVES - INTERIOR PLAINS REGION

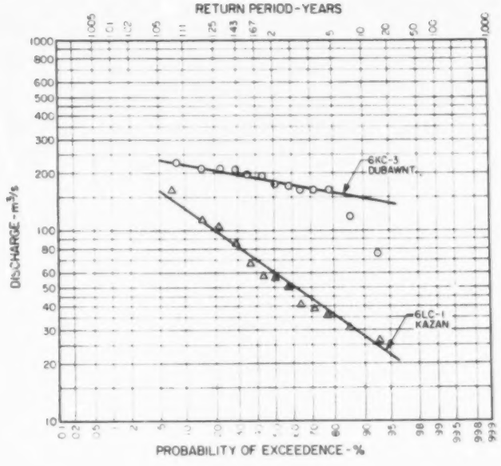
ACRES CONSULTING SERVICES LIMITED

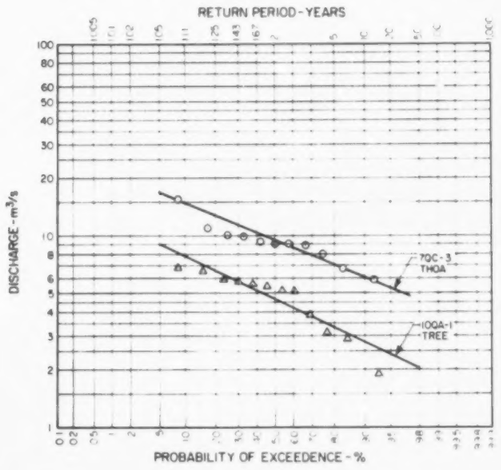
MARCH 1982

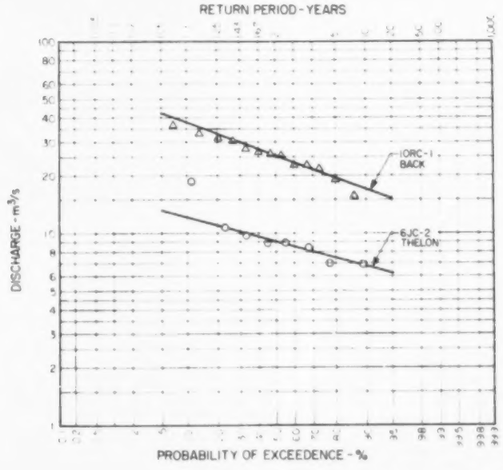
PLATE 16

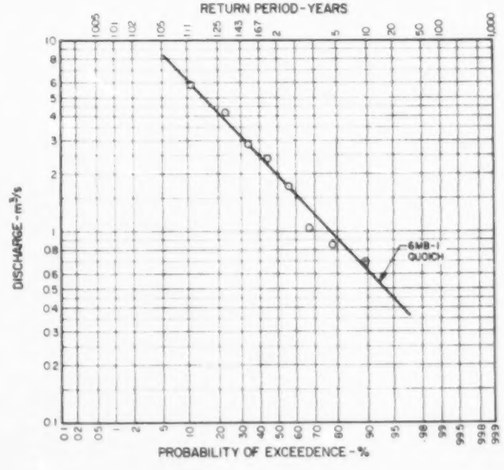












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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

30-DAY LOW FLOW FREQUENCY CURVES - CANADIAN SHIELD REGION

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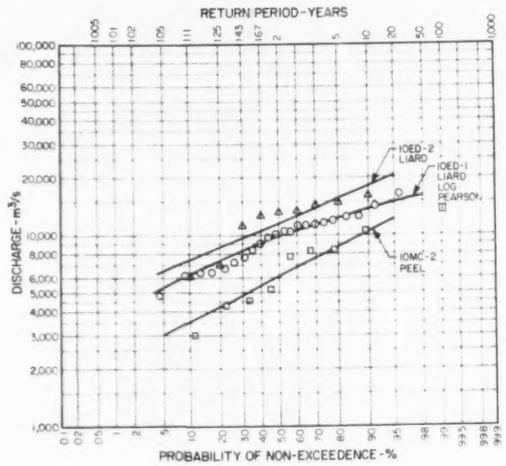
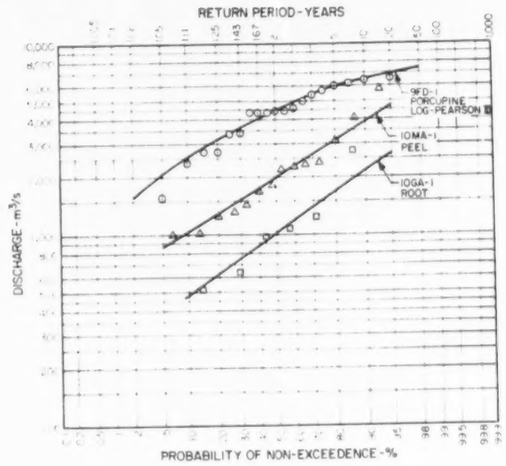
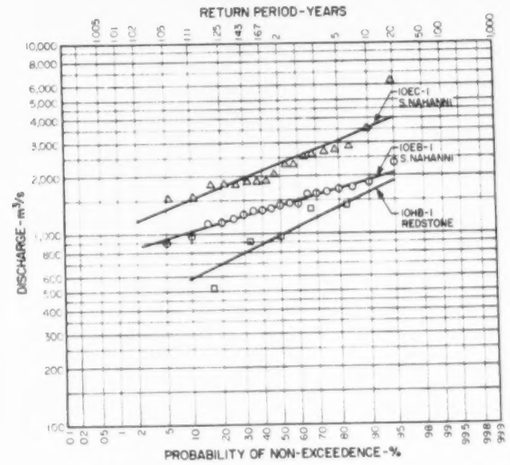
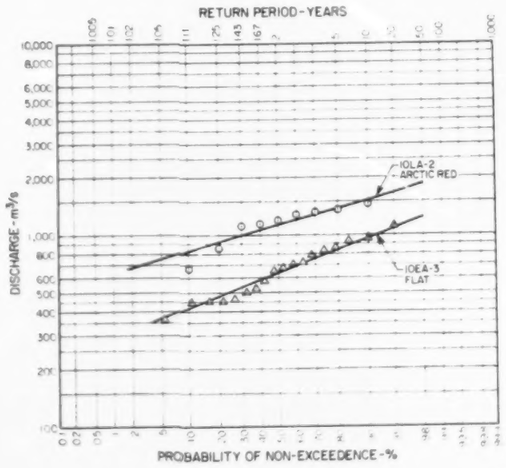
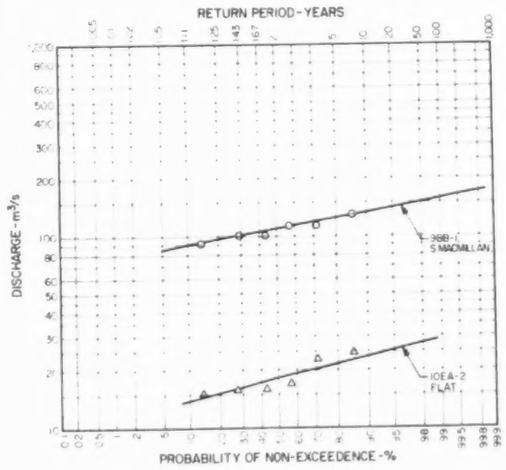
PLATE 17

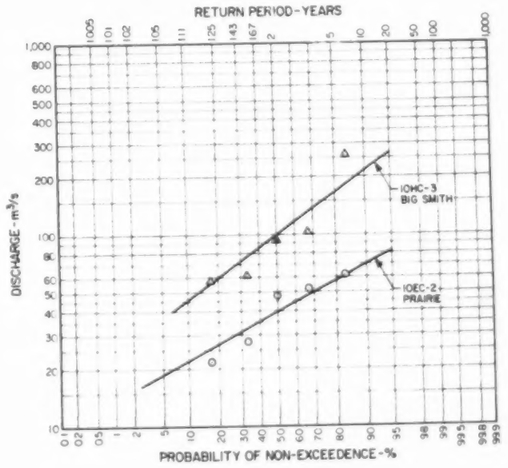












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NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOOD FREQUENCY CURVES - CORDILLERAN REGION

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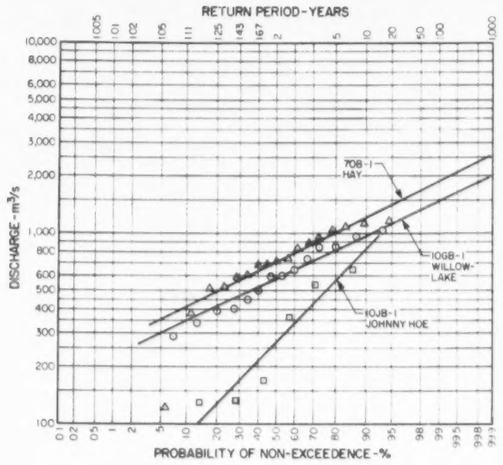
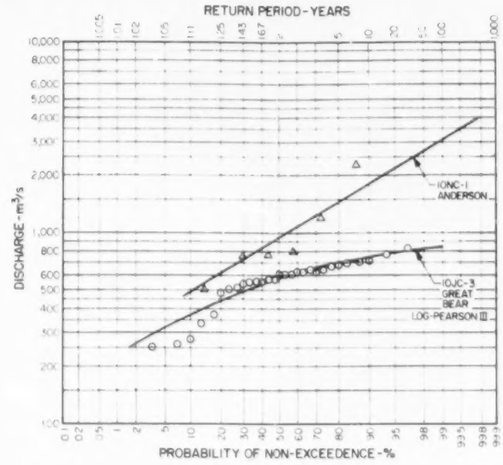
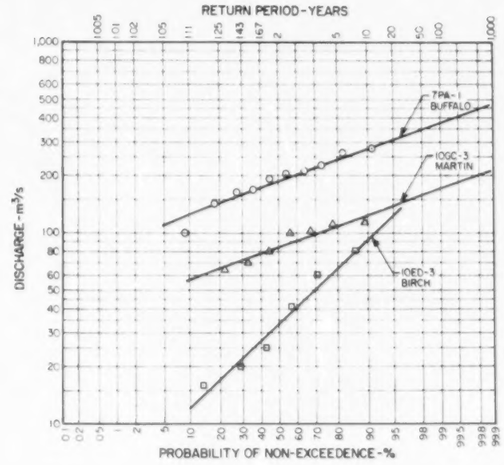
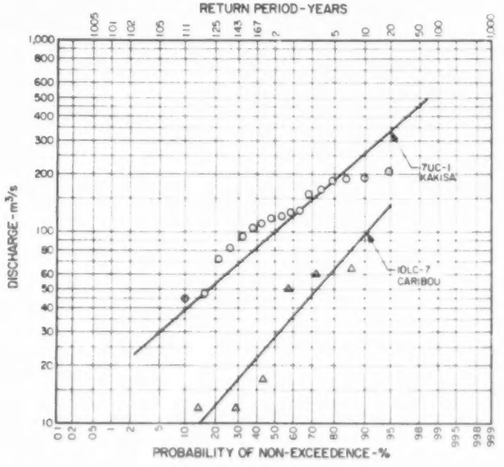
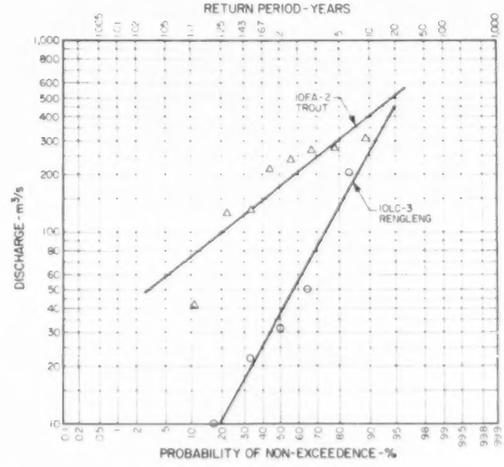
PLATE 18

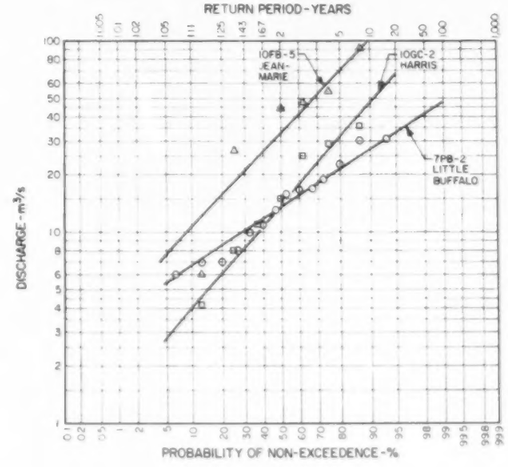












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NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOOD FREQUENCY CURVES - INTERIOR PLAINS REGION

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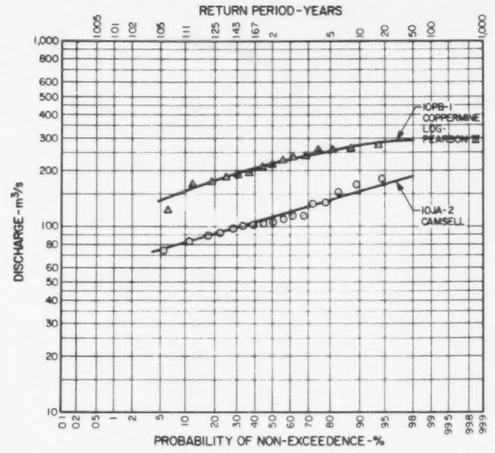
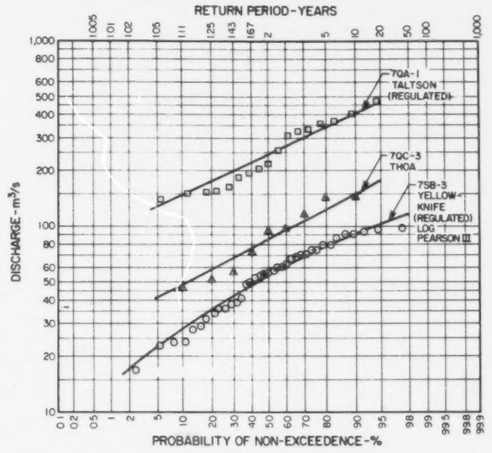
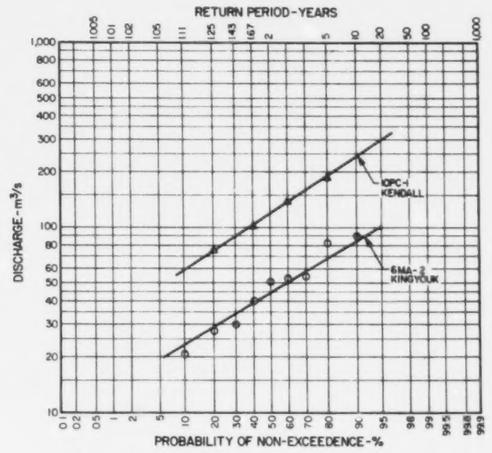
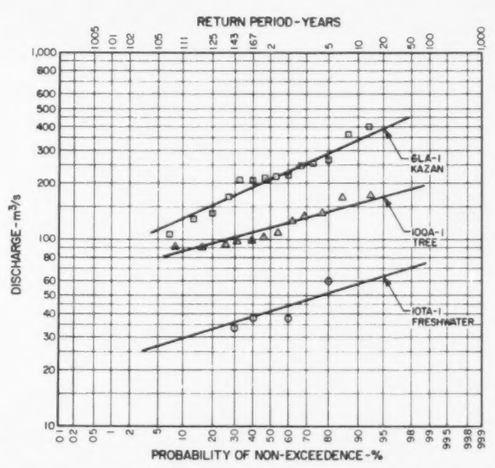
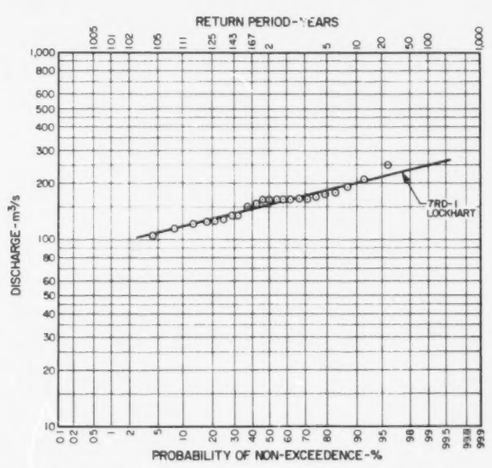
PLATE 19











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NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOOD FREQUENCY CURVES-CANADIAN SHIELD REGION

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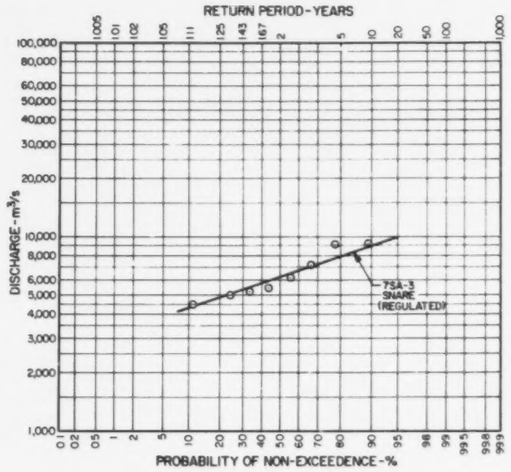
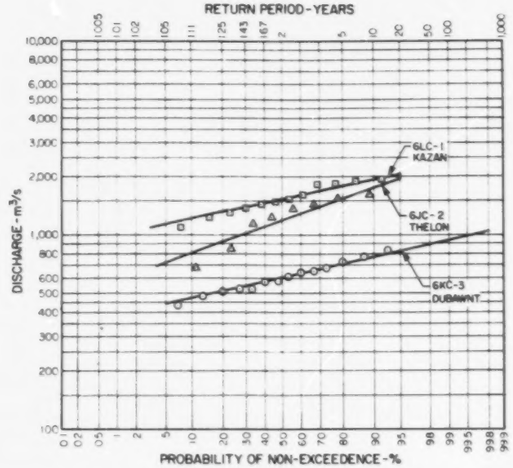
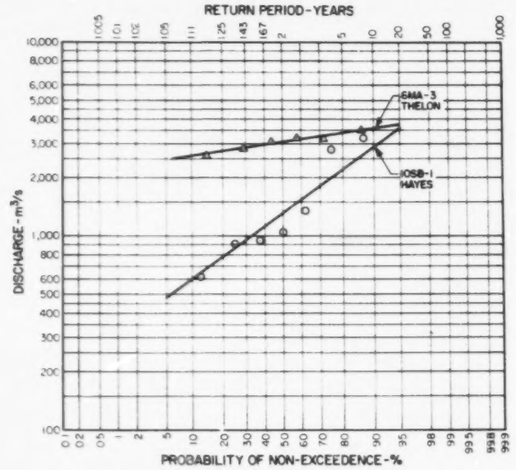
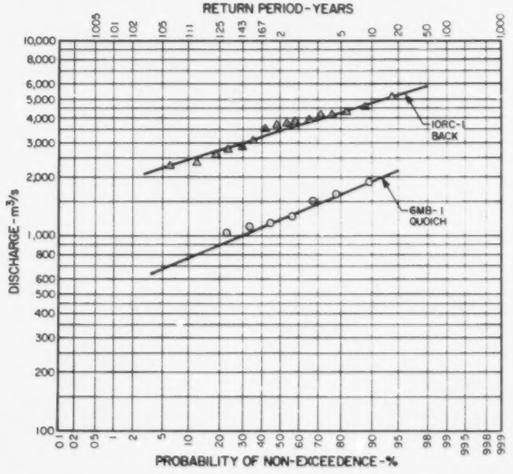
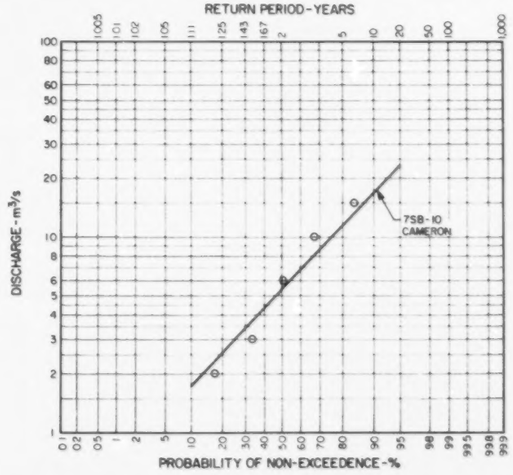
PLATE 20

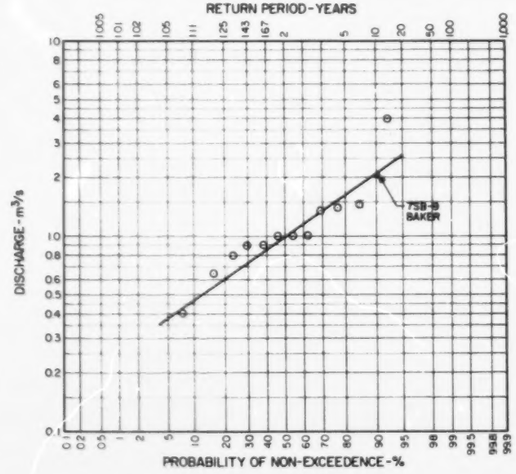












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NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOOD FREQUENCY CURVES - CANADIAN SHIELD REGION

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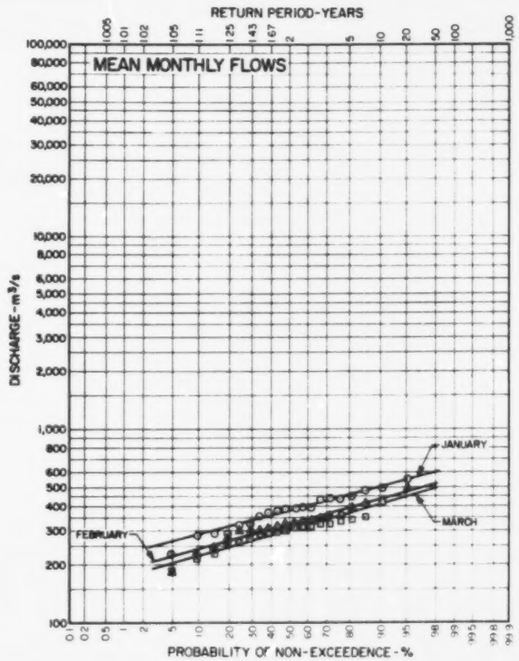

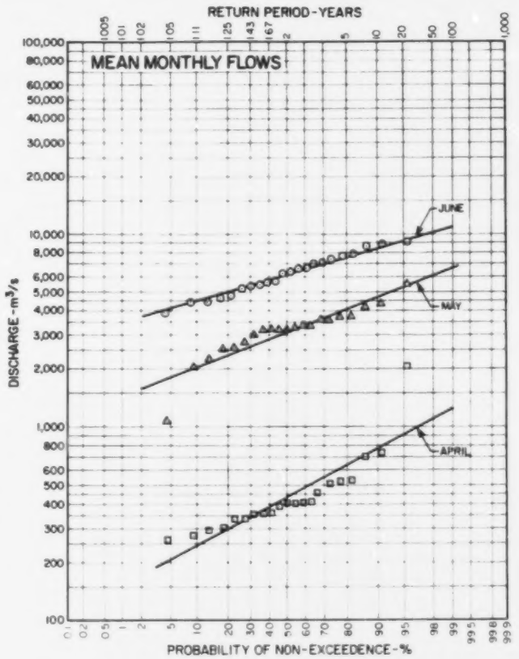

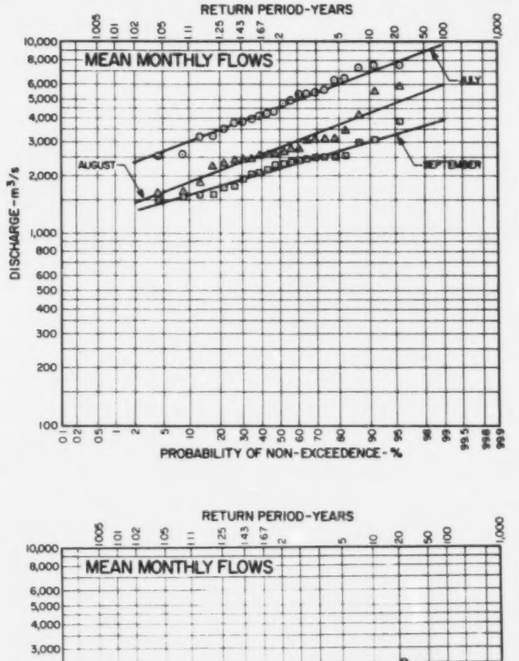

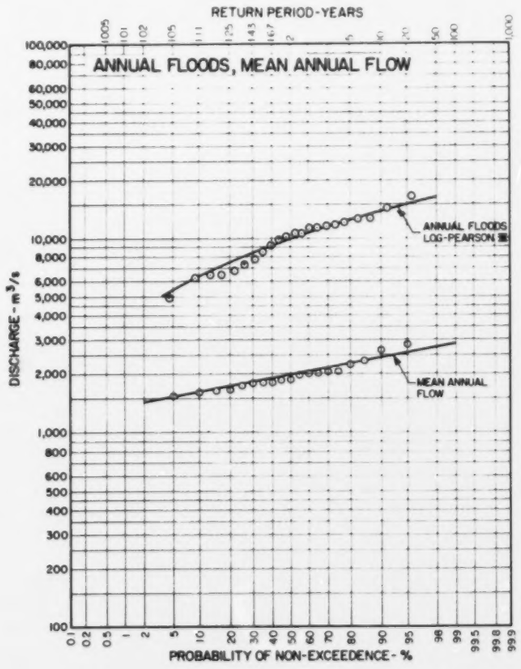

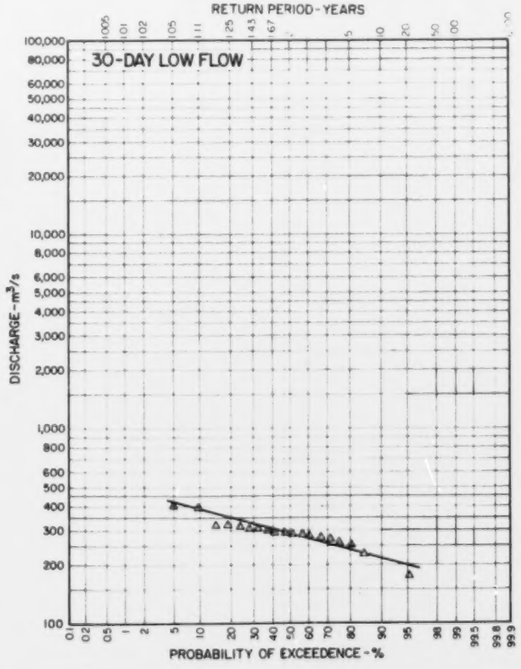

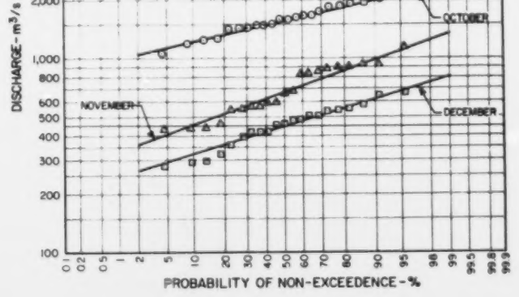

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOW FREQUENCY CURVES– LIARD RIVER AT FORT LIARD (10ED-1)

ACRES CONSULTING SERVICES LIMITED

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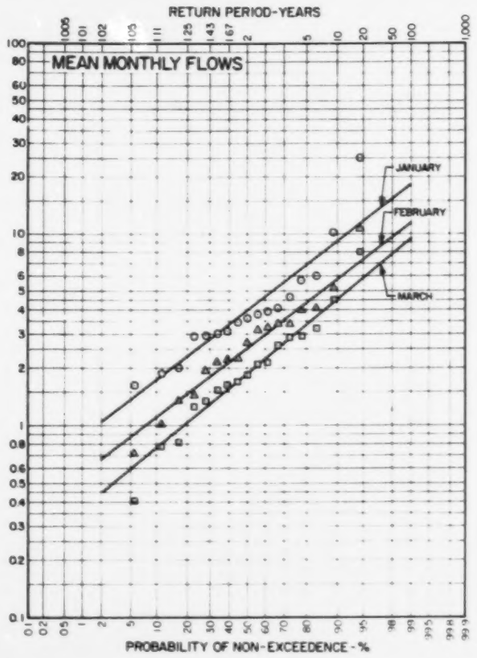
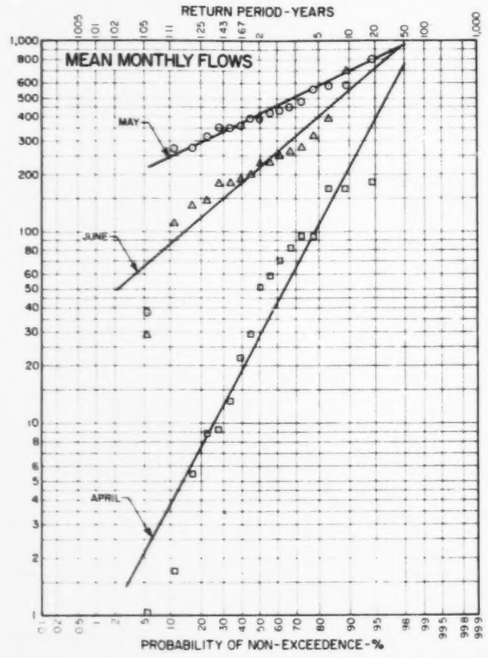
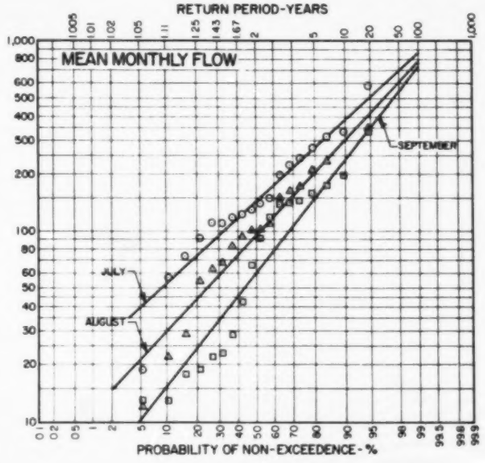
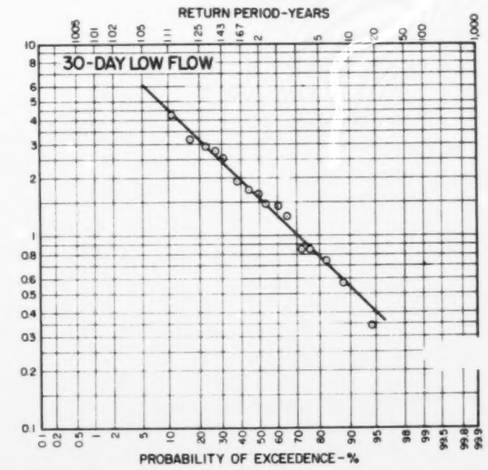
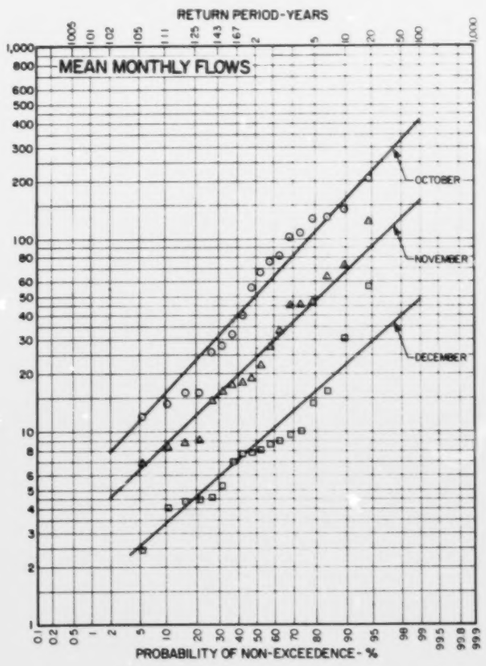
PLATE 22

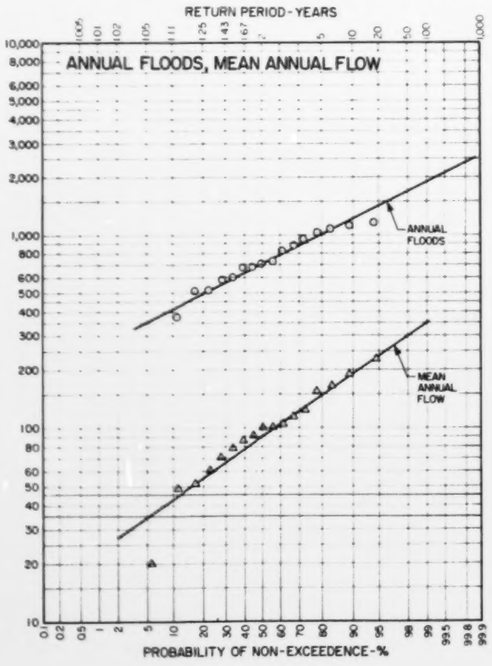












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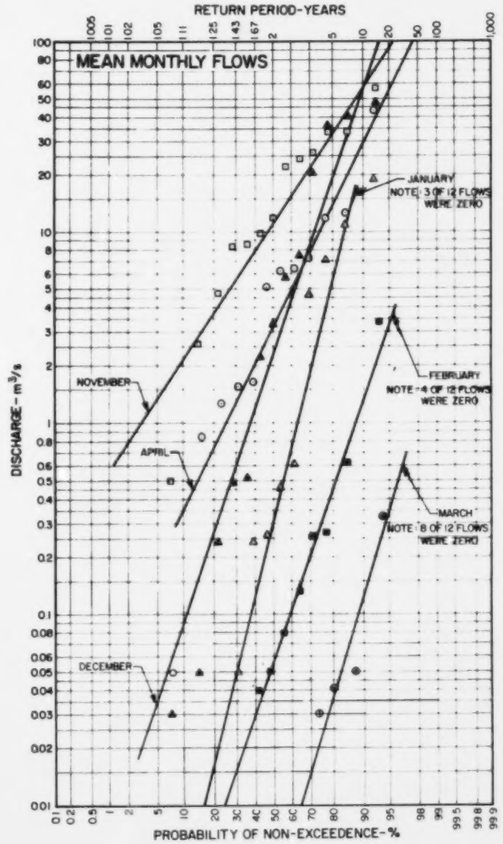
NORTHWEST TERRITORIES WATER RESOURCE STUDY

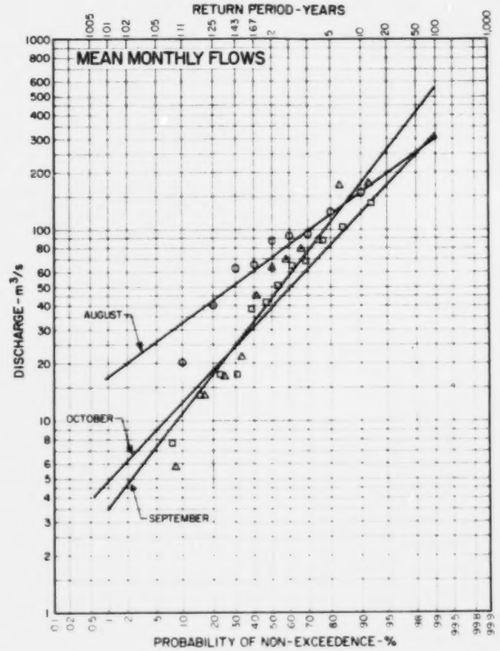
FLOW FREQUENCY CURVES- HAY RIVER AT HAY RIVER (70B-1)

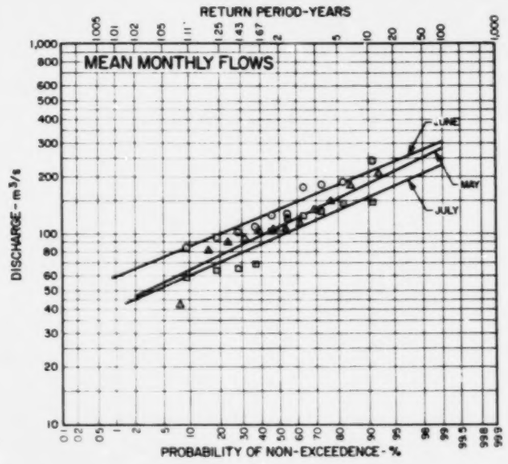
ACRES CONSULTING SERVICES LIMITED

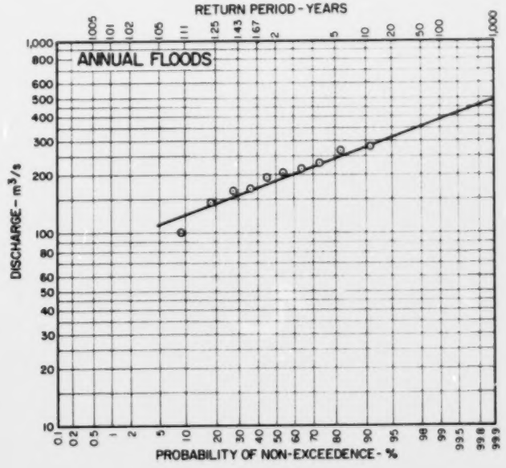
MARCH 1982

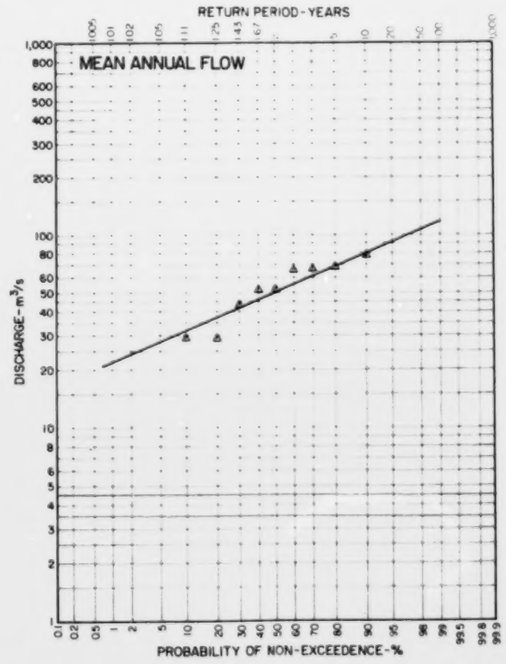
PLATE 23

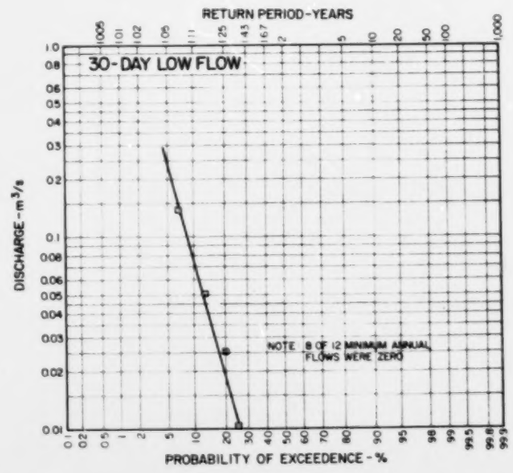












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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOW FREQUENCY CURVES– BUFFALO RIVER AT HIGHWAY 5 (7PA-I)

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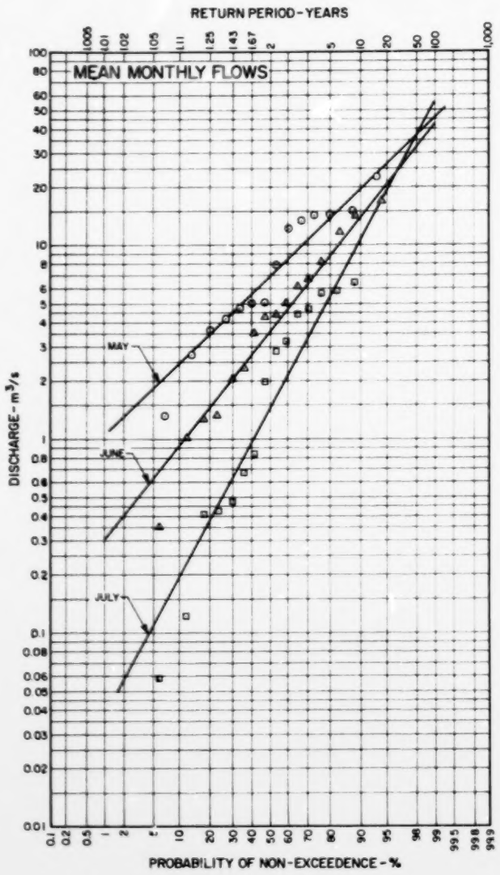
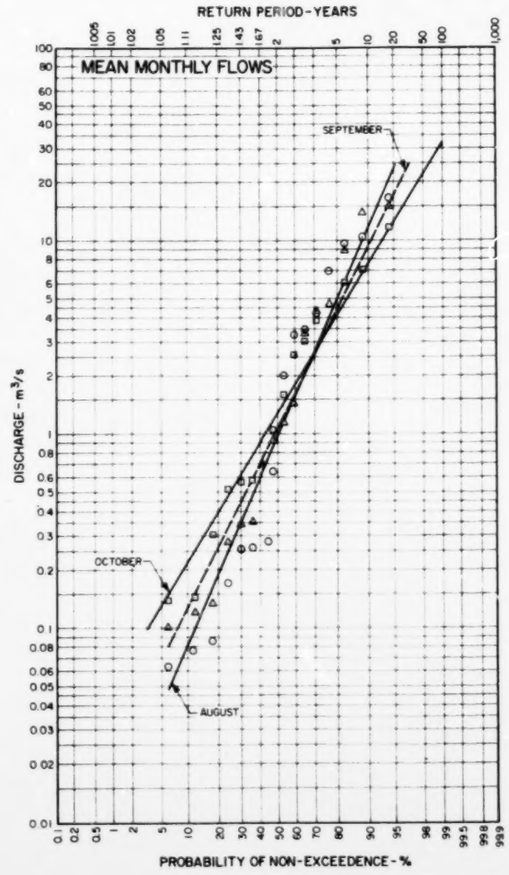
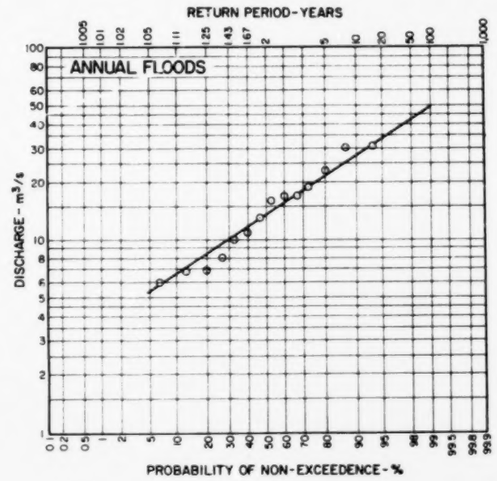
PLATE 24







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NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOW FREQUENCY CURVES - LITTLE BUFFALO RIVER NEAR PINE POINT HIGHWAY (7PB-2)

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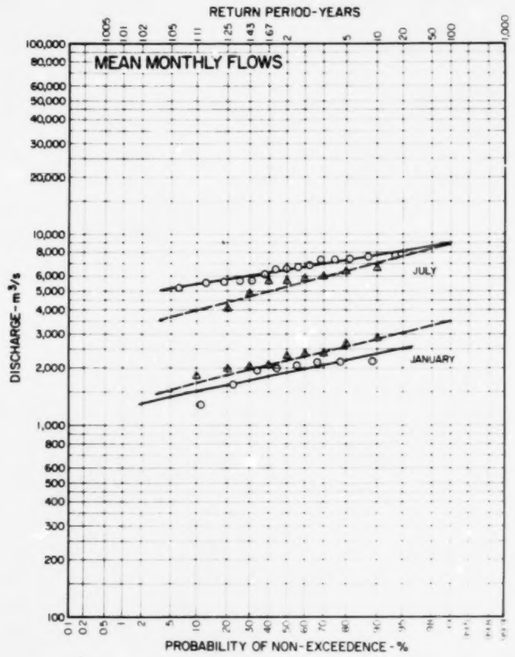
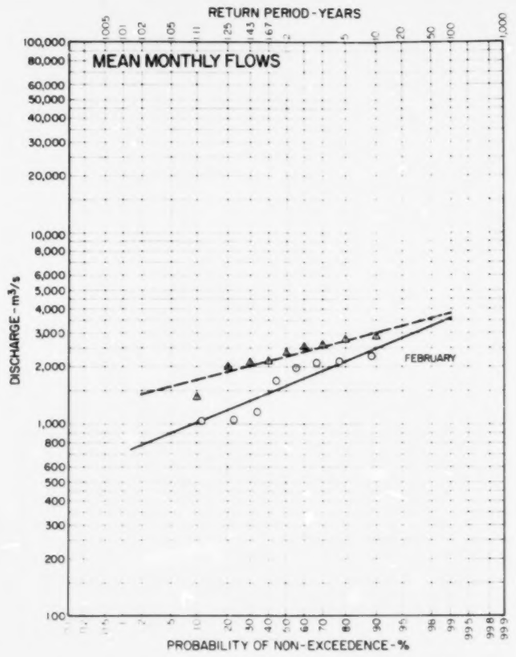
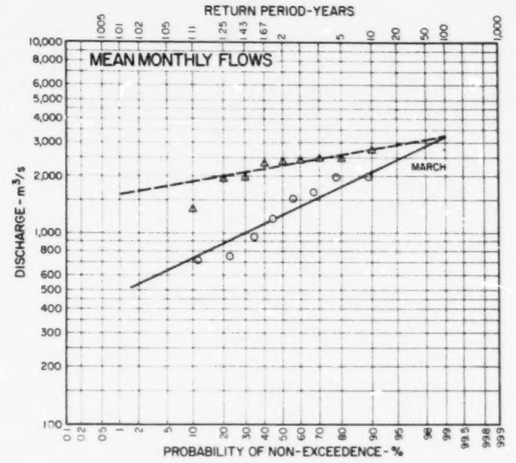
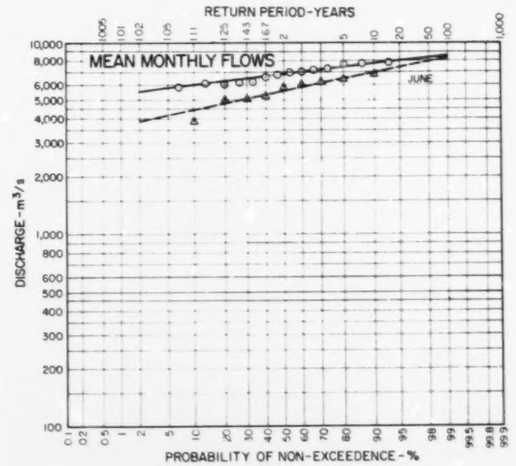
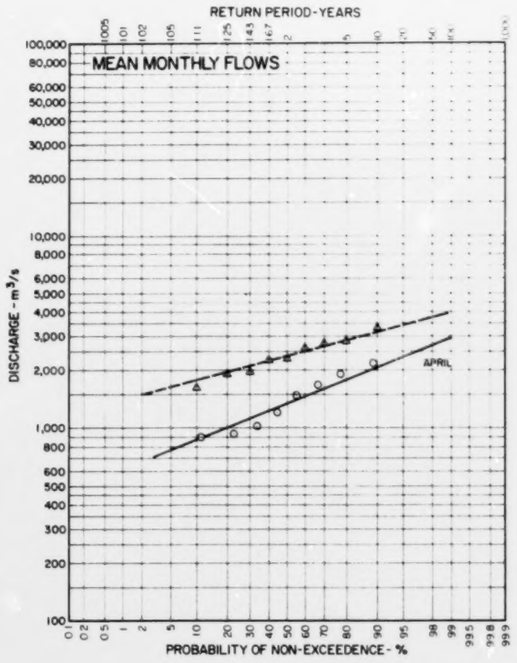
PLATE 25

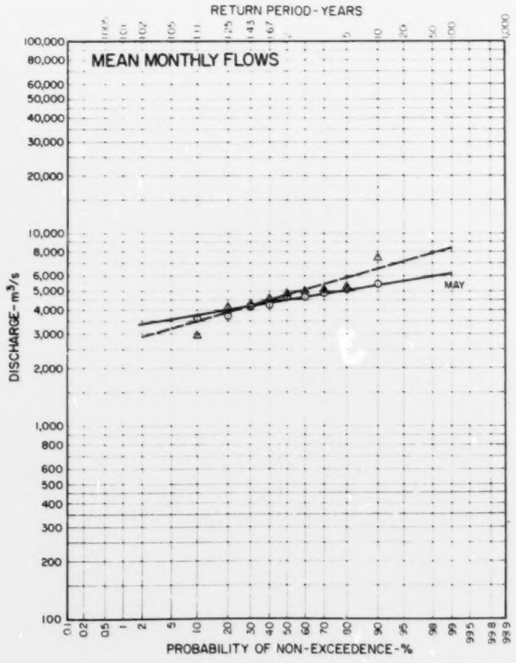












LEGEND

—○— UNTIL 1967 (WITHOUT REGULATION)

--△-- 1972 - 1980 (REGULATION ON 11.5% OF DRAINAGE AREA)

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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOW FREQUENCY CURVES - SLAVE RIVER AT FITZGERALD, ALBERTA (7NB-1)

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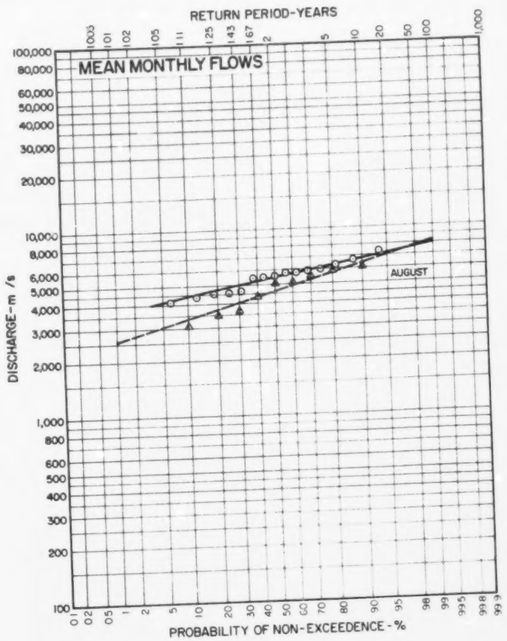

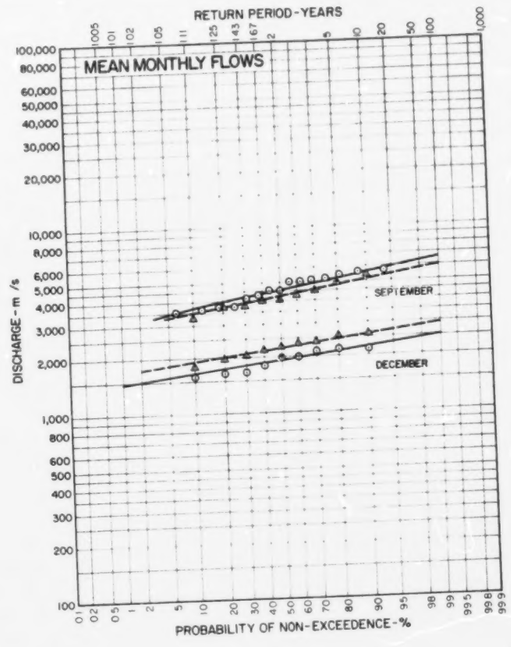

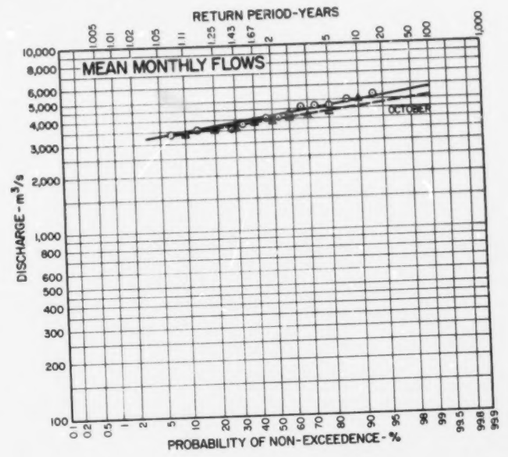

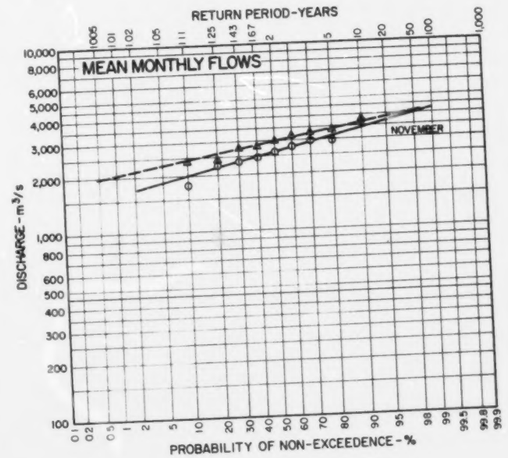

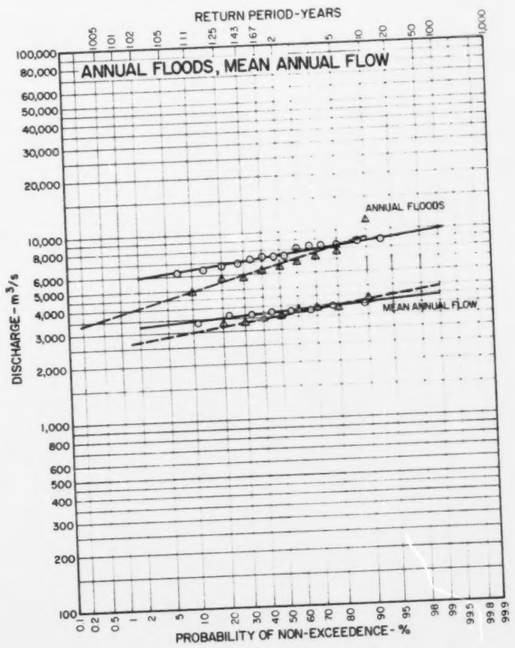

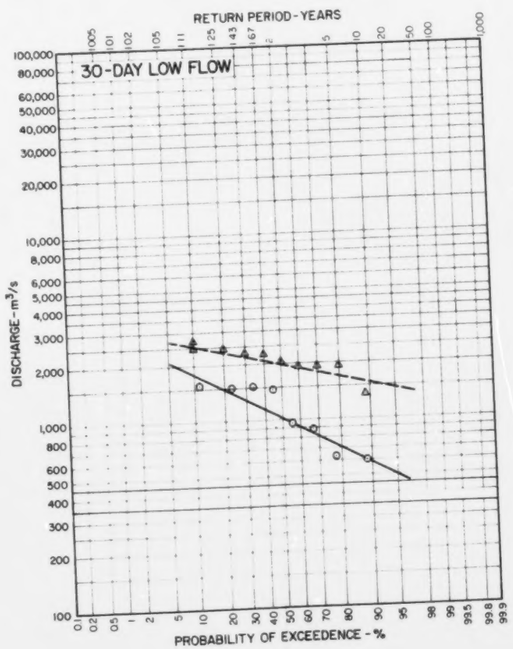

LEGEND

—○— UNTIL 1967 (WITHOUT REGULATION)

—△— 1972-1980 (REGULATION ON 11.5% OF DRAINAGE AREA)

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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

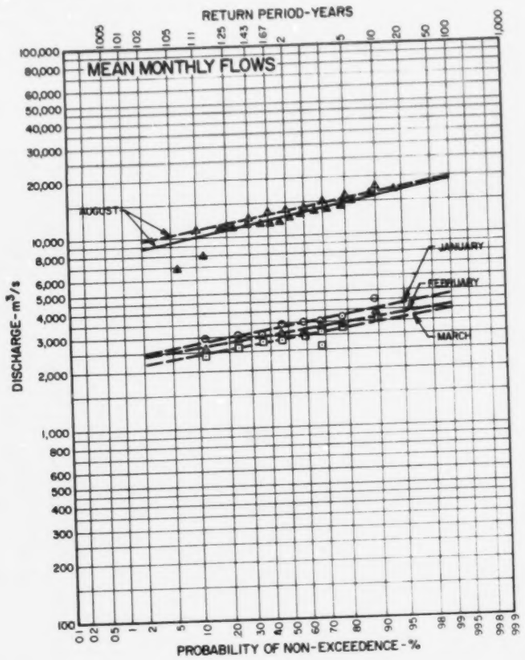
NORTHWEST TERRITORIES WATER RESOURCE STUDY

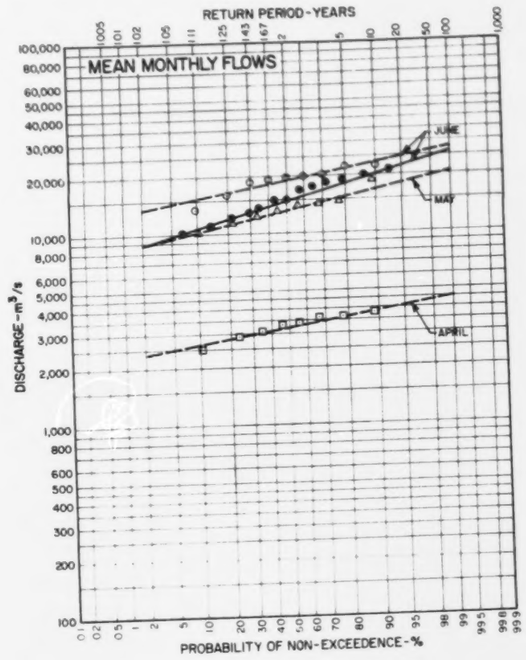
FLOW FREQUENCY CURVES- SLAVE RIVER AT FITZGERALD, ALBERTA (7NB-1)

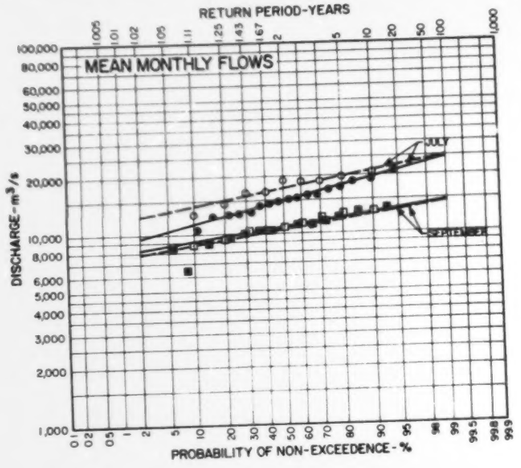
ACRES CONSULTING SERVICES LIMITED

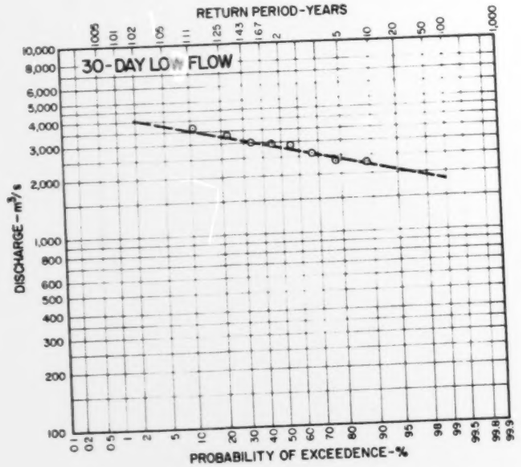
MARCH 1982

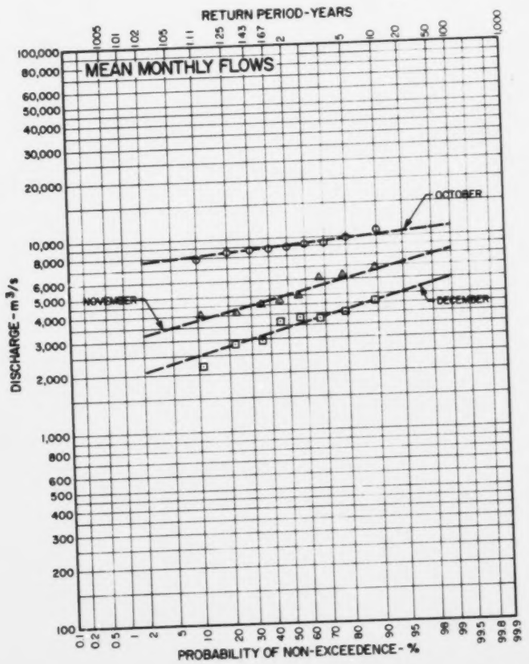
PLATE 27

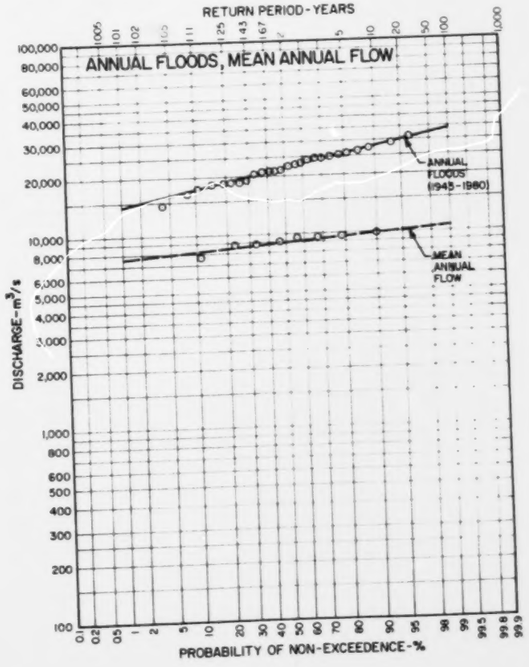












LEGEND

—○— UNTIL 1967 (WITHOUT REGULATION)

– –○– – 1972-1980 (REGULATION ON 4.5% OF DRAINAGE AREA)

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DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

NORTHWEST TERRITORIES WATER RESOURCE STUDY

FLOW FREQUENCY CURVES- MACKENZIE RIVER AT NORMAN WELLS (10KA-1)

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